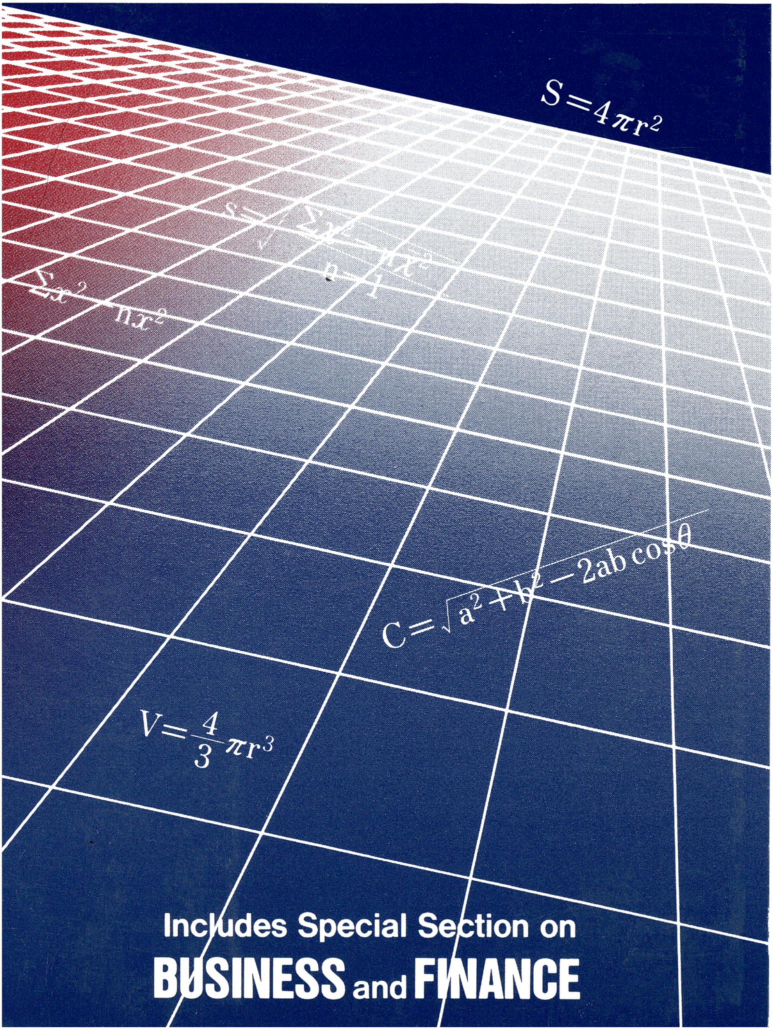
SHARP

EXPLORING THE SCIENCES II

For the EL-5150 Scientific Calculator Operation Manual plus Applications


$S=4\pi r^2$
$s=\sqrt{\frac{\Sigma x^2-nx^2}{n-1}}$
Σx^2-nx^2
$C=\sqrt{a^2+b^2-2ab\cos\theta}$
$V=\frac{4}{3}\pi r^3$

Includes Special Section on

BUSINESS and FINANCE

(ELECTRONIC CALCULATOR)
LIMITED WARRANTY:

SHARP ELECTRONICS CORPORATION warrants this product to the original purchaser to be free from defective materials and workmanship. Under this warranty the product will be repaired or replaced, at our option, without charge for parts or labor, with the exception of batteries, when returned to a SHARP CONSUMER FACTORY SERVICE CENTER listed in the instruction booklet supplied with your unit.

This warranty does not apply to any appearance items nor to any product whose exterior has been damaged or defaced, nor to any product subjected to misuse, abnormal servise or handling, nor to any products altered or repaired by other than a SHARP CONSUMER FACTORY SERVICE CENTER. This warranty does not apply to any product purchased outside the United States, its territories, or possessions.

The period of this warranty covers one (1) year on parts and one (1) year on labor from date of purchase.

This warranty entitles the original purchaser to have the warranted parts and labor rendered at no cost for the period of the warranty described above when the unit is carried or shipped, prepaid, to a SHARP CONSUMER FACTORY SERVICE CENTER together with proof of purchase.

THIS SHALL BE THE EXCLUSIVE WRITTEN WARRANTY OF THE ORIGINAL PURCHASER AND NEITHER THIS WARRANTY NOR ANY OTHER WARRANTY. EXPRESSED OR IMPLIED, SHALL EXTEND BEYOND THE PERIOD OF THE TIME LISTED ABOVE. IN NO EVENT SHALL SHARP BE LIABLE FOR CONSEQUENTIAL ECONOMIC DAMAGE OR CONSEQUENTIAL DAMAGE TO PROPERTY. SOME STATES DO NOT ALLOW A LIMITATION ON HOW LONG AN IMPLIED WARRANTY LASTS OR AN EXCLUSION OF CONSEQUENTIAL DAMAGE, SO THE ABOVE LIMITATION AND EXCLUSION MAY NOT APPLY TO YOU. IN ADDITION, THIS WARRANTY GIVES SPECIFIC LEGAL RIGHTS, AND YOU MAY HAVE OTHER RIGHTS WHICH VARY FROM STATE TO STATE.

FOR YOUR RECORDS ....

For your assistance in reporting this electronic calculator in case of loss or theft, please record below the model number and serial number which are located on the bottom of the unit.
Please retain this information.

Model Number EL 5150 Serial Number 67000135

Date of Purchase 87 Place of Purchase 47th St Photo

NOTICE

The material contained herein is supplied without representation or warranty of any kind. Sharp Electronics Corporation therefore assumes no responsibility and shall have no liability, consequential or otherwise, of any kind arising from the use of this material.

Contents

Chapter 1. Introduction 1
Names of Components 3
Operation Modes 6
Fundamentals of Operation 7
How to Use Protective Cover 12

Chapter 2. Operations in COMP Mode 13
Addition, Subtraction, Multiplication, & Division 15
Scientific Functions 18
Playback Function 30
Answer Memory Function 32
Continuous Calculation & Modify Functions 34
Memory Calculations 37
Binary, Octal, & Hexadecimal Number Calculations.... 43
Logical Operations 51
Statistical Calculations 54

Chapter 3. Operations in AER Mode 63
How to Use Algebraic Expression Reserve 65
Conditional Expression Judgment Function 77
Looping Function 83
Program Correction & Editing 87

Chapter 4. Display Systems & Decimal Places 91
Display Systems 92
Decimal Places 96

Appendixes 99
A. Operating Controls 100
B. Accuracy of Calculation 118
C. How to Check Remaining Bytes 123
D. Error Conditions & Messages 125
E. Priority Levels in Calculation & Pending Operations 127
F. Battery Replacement 130
G. Specifications 136
H. Scientific & Calculator Functions 139

NOTICE

- The contents of this manual are subject to change for improvements without notice.

- This calculator is provided with combinations of extremely sophisticated functions and has been shipped after thorough inspections including checks on the operations described in the Manual. Should you encounter any difficulties, contact your nearest SHARP distributor, dealer, or retailer. Your suggestions on the calculator are also invited. However, SHARP is not responsible for any consequences from the use of the calculator.

- SHARP is not responsible for any monetary loss or loss of profits from the use of any of the calculation examples contained in this manual or for any claims from a third party.

- SHARP is not responsible for any loss of, or damage to, the memory contents as a result of the repair or battery replacement of the calculator.

OPERATIONAL NOTES
(Handling Recommendations)

Because the liquid crystal display (LCD) of the EL-5150 is made of a liquid crystal hermetically sealed between two glass plates, adequate caution must be exercised in handling the calculator.

To ensure the trouble-free operation of the calculator, please observe the following points.

1. Do not carry the calculator in the back pocket of slacks or trousers.

2. Do not place the calculator in a location subject to direct sunlight, especially in a car with its window closed in hot climate. The calculator may be damaged due to high temperatures.

3. Do not place the calculator in a location exposed to high temperatures (e.g., near a heater). Also avoid locations subject to rapid temperature changes and excessive moisture or dust.

4. Do not drop or bump the calculator.

5. Do not use a cloth moistened with any volatile solvent or water to clean the calculator. Always use a soft, dry cloth.

If service should be required on this unit, use only a SHARP servicing dealer, SHARP approved service facility, or SHARP repair service where available.

CHAPTER 1

INTRODUCTION

Chapter 1 of this manual introduces you to the SHARP EL-5150 Scientific Calculator, a new and powerful computing instrument, by providing you with a basic understanding of the calculator.

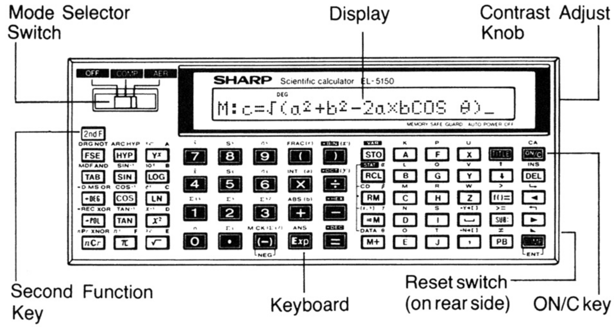
The EL-5150 allows direct entry of calculations and expressions (or formulas) as written. As you follow the detailed instructions and calculation examples in Chapters 2 and 3 of the manual, you will find that with this calculator you are not required to learn any machine or computer language, yet the unit provides you with formidable power in mathematical, scientific, engineering, and business calculations.

The EL-5150 features such unique functions as algebraic expression reserve function, conditional expression judgment and looping functions, and playback and answer memory functions. These important and useful functions are also detailed in Chapters 2 and 3, together with application examples.

Other items of supplemental information such as operating controls, error conditions, and so forth are included in Appendixes for ready reference.

Combined to the end of this manual is an application book that covers a number of programming and calculation exercises with the EL-5150 for applications in practically all scientific, engineering, and business fields.

Names of Components



- Mode selector switch

A 3-position slide switch used to turn on the power of the EL-5150 as well as to select either of the two operation modes of the unit: COMP and AER. (See Operation Modes on page 6 for details.)

- Keyboard

The keyboard consists of 66 keys arranged systematically in 14 columns by 4 or 5 rows, except that the 1st column (at the extreme left) has six keys. Of the many convenient keys, the two most frequently used keys are briefly introduced here to show their functions and locations.

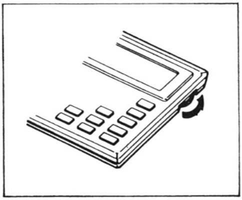
2nd Function key.............	A function change key used to designate the second function of another key. The second function of a key is printed in brown above the key.
ON/Clear · Clear .... All key	A clear/clear all key used to clear the contents of the display. This key is also used to turn on the power again when the calculator is automatically powered off. (See page 5 for details.)

- Display

A 24-digit liquid crystal display with each character formed in a pattern of 5×7 dots. (See Chapter 4 for details.)

- Contrast Adjust Knob

A control knob used to adjust the contrast of the LCD display. Turn this knob counterclockwise for higher contrast and clockwise for lower contrast.



- Reset switch

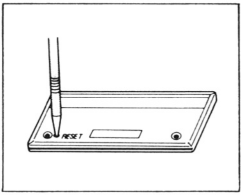
A switch used to retain or erase memory contents. When the EL-5150 is subjected to a large external noise or severe shock while in use, all the keys may become inoperative on rare occasions. Should such an abnormal condition occur in the calculator, take either of the following two actions:

(1) To retain memory contents
Set the Mode Selector switch to the COMP position and press the Reset switch, and the display will show the following.

```
                                          0.
```

The calculator can now perform a calculation while retaining its memory contents.

NOTE:
When pressing the Reset switch, depress the switch with a ball-point pen as shown in the illustration. Avoid use of a sharp-pointed pencil or equivalent with an easy-to-break point.



(2) To erase memory contents

Set the Mode Selector switch to the AER position and press the Reset switch. Check to see if the display shows the following:

```
ALL  CLEAR  ?  →ENT
```

If not, press the Reset switch again. If yes, press the ENT (COMP) key to erase the memory contents of the calculator. You can now perform programming. Memory contents will not be cleared when any key other than ENT (COMP) is pressed.

NOTE:

If the memory contents have been changed due to large external noise or severe shock, the memory contents may have already been erased despite the reset operations described in (1) and (2) above.

Auto-Power Off Feature

If no key is pressed for about 10 minutes, the power automatically turns off to conserve battery power. The memory is retained. (The actual time may be shorter or longer than 10 minutes depending upon the operating temperature or battery condition) To resume operation, press the ON/C key.

Operation Modes

The EL-5150 operates in two basic modes: COMP, an abbreviation for Computation and AER, an abbreviation for Algebraic Expression Reserve. To permit the calculator to operate in either of the two modes, the 3-position Mode Selector switch at the upper left corner of the keyboard must be set to the appropriate position as described below.

OFF (left)	Turns off the power. Memory contents will be retained.
COMP (center)	Turns on the power and places the unit in the COMP mode.
AER (right)	Turns on the power and places the unit in the AER mode.

COMP Mode

The COMP mode allows the calculator to perform all calculations ranging from the four basic arithmetic functions to algebraic expressions programmed in the AER mode. In this mode, the calculator normally performs calculations in the decimal number system. The calculator has special calculation modes: BIN, OCT, and HEX modes for calculations of binary, octal, and hexadecimal numbers respectively, plus STAT mode for statistical calculations.

AER Mode

The AER mode allows you to program algebraic and other expressions into the calculator, that is, to store them in memory for later use in COMP mode. (See Chapter 3 for details on program execution.)

This mode also has a special mode called the VAR mode in which you can enter lower-case letters, numbers (reduced in size), and Greek letters (α, β, γ, and θ) as variables for the expressions to be programmed.

Fundamentals of Operation

Key Operation

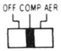
The EL-5150 is provided with a wide variety of functions including scientific and algebraic expression reserve functions as well as four basic arithmetic (add, subtract, multiply, and divide) functions. Here, the procedural steps in performing basic calculations are briefly covered to warm you up before going into the details described in Chapters 2 and 3.

(1) Power ON

As mentioned earlier, you will find a three-position slide switch at the upper left corner of the keyboard. This switch serves as a mode selector. Slide the switch from the OFF position to either the COMP or AER position and your calculator will be powered.

(2) Operation Mode Selection

The EL-5150 operates in two modes: COMP mode that allows the calculator to perform calculations and AER mode that allows the unit to store algebraic expressions in memory. For the purpose of explanation, the unit is put in the COMP mode by setting the mode selector switch to the COMP position.



(COMP mode is set)

Display:

```
                                        0.
```

NOTE:

When the unit is set in the COMP mode, message "COMP MODE" appears momentarily in the display and then "0." is displayed.

(3) Add, Subtract, Multiply, and Divide Functions

To perform any of the four basic functions with the EL-5150, enter the numeric data and press the algebraic keys ($\boxed{+}$, $\boxed{-}$, $\boxed{\times}$, $\boxed{\div}$, $\boxed{=}$) in the same sequence as you would do with any other scientific calculators.

Example 1:
To calculate 123 + 654 =

Key in:

$\boxed{1}\ \boxed{2}\ \boxed{3}\ \boxed{+}$

```
1 2 3+_
```

Key in:

$\boxed{6}\ \boxed{5}\ \boxed{4}$

```
1 2 3+6 5 4 _
```

Press:

$\boxed{=}$

```
                                   7 7 7.
```

Example 2:
To calculate 2.4×2 =

Key in:

$\boxed{2}\ \boxed{\cdot}\ \boxed{4}\ \boxed{\times}\ \boxed{2}$

```
2. 4×2_
```

Press:

$\boxed{=}$

```
                                     4. 8
```

If you make an error in key sequence and an error message appears in the display, press the ON/C key and enter the data again in the correct sequence. If you key in the incorrect data, use the ◄ or ► key to move the cursor over to the incorrect number or letter in the display and then enter the correct data. (See APPENDIX D for error messages.)

(4) Scientific functions
As an example of scientific functions, we will solve for the reciprocal of a number using the Reciprocal (x^{-1}) key.

Example:
To solve for $\frac{1}{8}$ = (or 8^{-1} =)

Key in:

8 2ndF x^{-1} =

```
                         0. 125
```

NOTE:
x^{-1} is the second function of x^2 and can be activated by pressing 2ndF key, then x^2 key.

Key Functions

- With the EL-5150, most of the keys have two functions, whereas some keys have three and some just one. The function printed on the key top is caused to occur when you press the key alone. The function printed in brown above the key is the second function of that key, and becomes effective only when the key is pressed following the function change key labeled "2nd F" as you have just done in the above calculation example.

NOTE:
The functions labeled "ENT" and "NEG" below the COMP and (−) keys respectively are not the second functions of these keys.

- Functions labeled " STAT , CD, (x, y), and DATA" in black at the left above the RCL , RM , ⇒M , and M+ keys respectively are those used for statistical calculations and are thus effective only in the STAT mode. (See page 54 for statistical calculation.) Functions labeled "α, β, γ, and θ" in black at the right above these keys are used for entry of characters as variables in the VAR mode.

- Functions labeled "**A**,**B**,**C**,**D**,**E**, and **F**" in black at the right above the Y^x , LOG , LN , x^2 , $\sqrt{\ }$, and π keys respectively are those used for entry of hexadecimal numbers in the HEX mode.

- Functions labeled "NOT, AND, OR, XOR, and XNOR" in black at the right above the FSE , TAB , →DEG , →POL and nCr keys respectively are those used to perform the logical operations of binary, octal, and hexadecimal numbers in the respective number system modes.

NOTE:
Multiply command "X" and upper-and lower-case letters "X" are distinguished from one another by indicating them on the dispay as follows:

X (letter) → X
X (multiply) → ×
2ndF VAR X (variable) → x

Conventions for Key Entry Descriptions

- In the following Chapters, key operations and key functions are described whenever possible as shown in the following examples.

key	Key operation	Designated function
SIN^{-1} $\boxed{\text{SIN}}$	$\boxed{\text{2ndF}}$ $\boxed{\text{SIN}^{-1}}$	SIN^{-1}
	$\boxed{\text{SIN}}$	SIN
$\sqrt[3]{\ }$ **E** $\boxed{\sqrt{\ }}$	$\boxed{\text{E}}$	Hexadecimal number **E**
	$\boxed{\text{2ndF}}$ $\boxed{\sqrt[3]{\ }}$	$\sqrt[3]{\ }$
	$\boxed{\sqrt{\ }}$	$\sqrt{\ }$
CD β $\boxed{\text{RM}}$	$\boxed{\beta}$	Greek letter "β"
	$\boxed{\text{CD}}$	CD
	$\boxed{\text{RM}}$	RM

- All numeric keys for data entry are not enclosed in a box unlike other boxed keys indicating that they are the keys pressed.

$\boxed{1}$ $\boxed{2}$ $\boxed{3}$ $\boxed{\cdot}$ $\boxed{4}$ → 123.4 (decimal number)

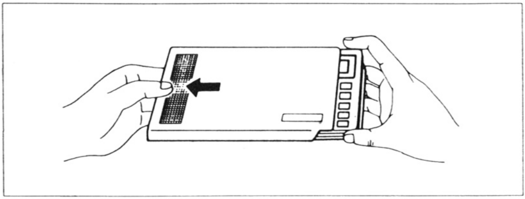
$\boxed{2}$ $\boxed{\text{B}}$ $\boxed{\text{C}}$ → 2BC (hexadecimal number)

- The word "key in" or "press" before each key operation is omitted.

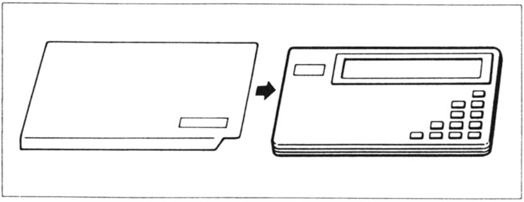
How to Use Protective Cover

The protective plastic cover with instruction labels attached to its inside is supplied as an accessory for protecting the calculator against shock. When you are not using the unit or carrying it in your briefcase, be sure to attach the protective cover to the unit.

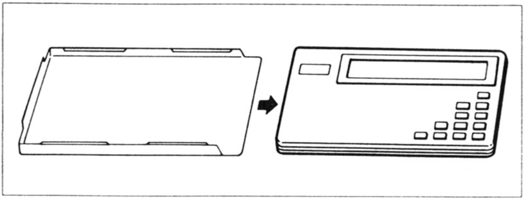
- Removing the cover



- Attaching the cover when the unit is not in use



- Attaching the cover while the unit is in use



CHAPTER 2
OPERATIONS IN COMP MODE

Before operating each calculation example in this chapter, make sure that the Mode Selector switch is in the COMP position and then press the [ON/C] key to clear the calculator. Unless otherwise stated, all the following calculation examples are to be performed in the floating decimal point system.

If any of the **FIX** , **SCI** , and **ENG** indicators is appearing in the display, press the [FSE] key consecutively until none of these indicators appears, indicating that your calculator's display is in the floating decimal point mode.

Addition, Subtraction, Multiplication, & Division

Examples shown here are the mixed calculations of the four basic functions.

NOTE:

This calculator uses algebraic logic. Calculations are not necessarily performed in the order entered. For example, multiplication is carried out before addition. Priority levels in calculation are detailed in APPENDIX E.

Example 1:

$49.6 - 75.2 + 32 =$

$\boxed{\text{ON/C}}$ 49.6 $\boxed{-}$ 75.2 $\boxed{+}$ 32 $\boxed{=}$

```
6.4
```

Example 2:

$45 + 285 \div 3 =$

45 $\boxed{+}$ 285 $\boxed{\div}$ 3 $\boxed{=}$

```
140.
```

Example 3:

$(45 + 285) \div 3 =$

$\boxed{(}$ 45 $\boxed{+}$ 285 $\boxed{)}$ $\boxed{\div}$ 3 $\boxed{=}$

```
110.
```

NOTE:

The parenthesis keys specify which group of numbers to calculate first whenever there is a choice. If you omitted parentheses, your answer would be 140 as in Example 2 because division takes precedence over addition. (See APPENDIX E for details on priority levels.)

Example 4:

$42\times(-5)+120=$

42 $\boxed{\times}$ $\boxed{(-)}$ 5 $\boxed{+}$ 120 $\boxed{=}$

-90.

NOTE:

When you enter a negative number, press $\boxed{(-)}$ before the negative number.

Example 5:

$(5\times10^{3})\div(4\times10^{-3})=$

5 $\boxed{\mathrm{Exp}}$ 3 $\boxed{\div}$ 4 $\boxed{\mathrm{Exp}}$ $\boxed{(-)}$ 3 $\boxed{=}$

1250000.

NOTE:

$\boxed{\mathrm{Exp}}$ is used to enter the exponent part of a number.

Example 6:

$72\times(((56+23)\times2)-72\div4)=$

$\underset{\overset{\uparrow}{\textcircled{1}}}{72}$ $\boxed{(}$ $\boxed{(}$ $\boxed{(}$ 56 $\boxed{+}$ 23 $\boxed{)}$ $\boxed{\times}$ 2 $\boxed{)}$

$\boxed{-}$ 72 $\boxed{\div}$ $\underset{\overset{\uparrow}{\textcircled{2}}}{4}$ $\boxed{=}$

10080.

NOTE:

1. As in ① above, the multiply key immediately before the open parenthesis may be omitted.
2. As in ② above, the closed parenthesis before the equals key may be omitted.
3. Plural parentheses may be entered in an expression with other calculation commands for more complicated arithmetic sequences, provided that the number of pending operations in the calculator does not exceed 16 and the number of pending values in the calculator does not exceed 8. (See APPENDIX E for details on pending operations.)

Scientific Functions

Scientific calculations are performed in the same manner as basic calculations. As you will note in the following examples, scientific funtions are entered as you would normally read them.

Trigonometric Functions

When you solve for any of the trigonometric and inverse trigonometric functions, you must first designate the unit of angle applicable to the function using the 2ndF and DRG keys. As these two keys are pressed consecutively, the indications "DEG", "RAD", and "GRAD" appear alternately at the upper part of the display. Keep pressing 2ndF DRG until the desired unit of angle is set on the display.

DEG: Degree [°]
RAD: Radian [RAD]
GRAD: Grad [g]

$90[°] = \frac{\pi}{2}\,[\text{RAD}] = 100\,[\text{g}]$

NOTE:

The designated unit of angle will be retained in memory even when the power is turned off.
Therefore, you need not redesignate the angular unit each time the power is turned on.

Example 1:

SIN 63 =
Angular unit: DEG

SIN 63 =

```
          DEG
                    0. 891006524
```

Example 2:

$\mathrm{COS}\,\frac{\pi}{4} =$

Angular unit: RAD

`COS` `(` `π` `÷` 4 `)` `=`

```
                RAD
                      0.707106781
```

NOTE:
To solve for the value for an expression as in $\mathrm{COS}\,\frac{\pi}{4}$, parenthesize the expression.

Example 3:

TAN150 =

Angular unit: GRAD

`TAN` 150 `=`

```
                GRAD
                              -1.
```

Inverse Trigonometric Functions

The calculation results of the respective inverse trigonometric functions are expressed within the following limits.

$\theta = \mathrm{SIN}^{-1}x, \theta = \mathrm{TAN}^{-1}x$	$\theta = \mathrm{COS}^{-1}x$
DEG : $-90 \leqq \theta \leqq 90$	DEG : $0 \leqq \theta \leqq 180$
RAD : $-\frac{\pi}{2} \leqq \theta \leqq \frac{\pi}{2}$	RAD : $0 \leqq \theta \leqq \pi$
GRAD: $-100 \leqq \theta \leqq 100$	GRAD: $0 \leqq \theta \leqq 200$

In addition to the designation of the unit of angle using the [2ndF] and [DRG] keys, you must use the [2ndF] key for each calculation example here to designate the second function of another key.

Example 1:

$\mathrm{COS}^{-1}\ 0.5 =$
Angular unit: DEG

[2ndF] [COS^{-1}] .5 [=]

```
              DEG
                                        60.
```

Example 2:

$\mathrm{SIN}^{-1}\ -1 =$
Angular unit: RAD

[2ndF] [SIN^{-1}] [(−)] 1 [=]

```
              RAD
                     −1.570796327
```

Example 3:

$\mathrm{TAN}^{-1}\ 1 =$
Angular unit: GRAD

[2ndF] [TAN^{-1}] 1 [=]

```
              GRAD
                                        50.
```

Hyperbolic and Inverse Hyperbolic Functions

When using any of the hyperbolic and inverse hyperbolic functions, the “HYP” indicator will appear at the upper part of the display.

Example 1:

SINH 4 =

$\boxed{\text{HYP}}$ $\boxed{\text{SIN}}$ 4 $\boxed{=}$

```
27.2899172
```

Example 2:

$(\text{COSH}\ 1.5 + \text{SINH}\ 1.5)^2 =$

$\boxed{(}$ $\boxed{\text{HYP}}$ $\boxed{\text{COS}}$ 1.5 $\boxed{+}$ $\boxed{\text{HYP}}$ $\boxed{\text{SIN}}$ 1.5 $\boxed{)}$ $\boxed{x^2}$ $\boxed{=}$

```
20.08553692
```

Example 3:

$\text{SINH}^{-1}\ 9 =$

$\boxed{\text{2ndF}}$ $\boxed{\text{ARCHYP}}$ $\boxed{\text{SIN}}$ 9 $\boxed{=}$

```
2.893443986
```

Example 4:

$\text{TANH}^{-1}\ \frac{5}{7} =$

$\boxed{\text{2ndF}}$ $\boxed{\text{ARCHYP}}$ $\boxed{\text{TAN}}$ $\boxed{(}$ 5 $\boxed{\div}$ 7 $\boxed{)}$ $\boxed{=}$

```
0.895879735
```

Exponential Functions

Example 1:

$e^3 =$

$\boxed{\text{2ndF}}$ $\boxed{e^x}$ 3 $\boxed{=}$

```
20.08553692
```

Example 2:

$10^{1.7} =$

$\boxed{\text{2ndF}}\ \boxed{10^x}$ 1.7 $\boxed{=}$

```
50.11872336
```

Logarithmic Functions (Natural and Common Logarithms)

Example 1:

LN 20 =

$\boxed{\text{LN}}$ 20 $\boxed{=}$

```
2.995732274
```

Example 2:

LOG 50 =

$\boxed{\text{LOG}}$ 50 $\boxed{=}$

```
1.698970004
```

Squaring

Example:

$5^2 - 4^2 =$

5 $\boxed{x^2}\ \boxed{-}$ 4 $\boxed{x^2}\ \boxed{=}$

```
9.
```

Reciprocals

Example:

$$\frac{1}{8} =$$

8 $\boxed{\text{2ndF}}$ $\boxed{x^{-1}}$ $\boxed{=}$

```
0.125
```

Square Root and Cubic Root

Example 1:

$$\sqrt{49} + \sqrt{64} =$$

$\boxed{\sqrt{\ }}$ 49 $\boxed{+}$ $\boxed{\sqrt{\ }}$ 64 $\boxed{=}$

```
15.
```

Example 2:

$$\sqrt[3]{123 \times 6} =$$

$\boxed{\text{2ndF}}$ $\boxed{\sqrt[3]{\ }}$ $\boxed{(}$ 123 $\boxed{\times}$ 6 $\boxed{)}$ $\boxed{=}$

```
9.036885658
```

Power

Example 1:

$$3^4 =$$

3 $\boxed{Y^x}$ 4 $\boxed{=}$

```
81.
```

Example 2:

$8^{-2} =$ (or $\frac{1}{8^{2}} =$)

$8\ \boxed{Y^{x}}\ \boxed{(-)}\ 2\ \boxed{=}$

```
0.015625
```

Example 3:

$(12^{3})^{\frac{1}{4}} =$ (or $\sqrt[4]{12^{3}} =$)

$12\ \boxed{Y^{x}}\ 3\ \boxed{Y^{x}}\ 4\ \boxed{\text{2ndF}}\ \boxed{x^{-1}}\ \boxed{=}$

```
6.447419591
```

Power Root

Example:

$\sqrt[4]{81} =$

$4\ \boxed{\text{2ndF}}\ \boxed{\sqrt[x]{\ }}\ 81\ \boxed{=}$

```
3.
```

Factorial

Example:

$6! = (6 \times 5 \times 4 \times 3 \times 2 \times 1 =)$

$6\ \boxed{\text{2ndF}}\ \boxed{n!}\ \boxed{=}$

```
720.
```

Permutations

Formula:

$$nPr=\frac{n!}{(n-r)!}$$

Example:
From a group of 10 persons, you must decide how each combination of 3 persons should be lined up. What is the total number of ways the different groups of 3 can be arranged?

10 $\boxed{\text{2ndF}}$ $\boxed{nPr}$ 3 $\boxed{=}$

```
720.
```

Combinations

Formula:

$$nCr=\frac{n!}{r!(n-r)!}$$

Example:
You must select 3 persons from a group of 10. How many different combinations of 3 persons can be formed?

10 $\boxed{nCr}$ 3 $\boxed{=}$

```
120.
```

Conversions of Coordinates

Two keys are used for conversions of coordinates.

$\boxed{\to\text{POL}}$: Converts rectangular coordinates (x, y) into polar coordinates (r, θ)

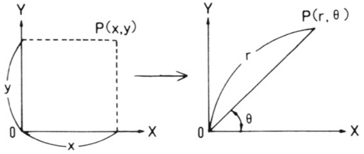
$\boxed{\to\text{REC}}$: Converts polar coordinates into rectangular coordinates (x, y)

NOTE:
Because the calculator uses memory register Z to store the value of θ or y obtained from the conversion of coordinates, the contents of memory Z will be changed as the result of the conversion.

- Conversion of rectangular coordinates into polar coordinates (x, y → r, θ)

The value of θ is obtained within the following limits:

DEG :$0 \leqq |\theta| \leqq 180$
RAD :$0 \leqq |\theta| \leqq \pi$
GRAD:$0 \leqq |\theta| \leqq 200$

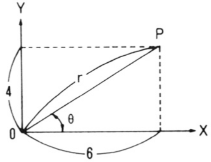


$$r=\sqrt{x^2+y^2},\ \theta=\mathrm{TAN}^{-1}\frac{y}{x}$$

Before you start the conversion, press the $\boxed{\text{2ndF}}$ and $\boxed{\text{DRG}}$ keys to designate the desired angular unit.

Example 1:

To solve for the values of polar coordinates (r, θ) with rectangular coordinates at point P (x = 6, y = 4)



Angular unit: DEG

6 $\boxed{\text{→POL}}$ 4 $\boxed{=}$

```
DEG
            7.211102551
```

(Answer for r)

$\boxed{\text{RCL}}$ $\boxed{\text{Z}}$ (or $\boxed{\text{Z}}$ $\boxed{=}$)

```
DEG
            33.69006753
```

(Answer for θ)

Example 2:

To solve for the magnitude and direction (phase) of a vector with i = 12 + j9

Angular unit: DEG

12 $\boxed{\rightarrow\text{POL}}$ 9 $\boxed{=}$

```
DEG
                                   1 5.
```

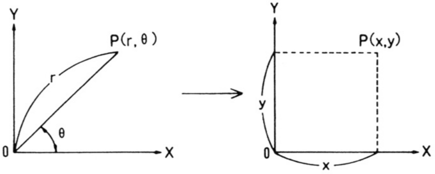
(Answer for magnitude)

$\boxed{\text{RCL}}$ $\boxed{\text{Z}}$ (or $\boxed{\text{Z}}$ $\boxed{=}$)

```
DEG
                 3 6. 8 6 9 8 9 7 6 5
```

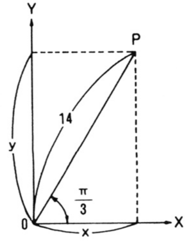
(Answer for direction)

- Conversion of polar coordinates into rectangular coordinates (r, θ → x, y)



Expression:
$x = r\,\mathrm{COS}\,\theta,\ y = r\,\mathrm{SIN}\,\theta$

Example:
To solve for the values of rectangular coordinates (x, y) with polar coordinates at point P ($r = 14, \theta = \frac{\pi}{3}$)



Angular unit: RAD

14 $\boxed{\text{2ndF}}$ $\boxed{\rightarrow\text{REC}}$ $\boxed{(}$ $\boxed{\pi}$ $\boxed{\div}$ 3 $\boxed{)}$ $\boxed{=}$

```
RAD
                                    7.
```

(Answer for x)

[RCL] [Z] (or [Z] [=])

```
RAD
                12. 12435565
```

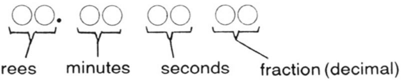
(Answer for y)

Conversions of Angles

Two keys are used for conversions of angles.

[→DEG] : Converts an angle in the sexagesimal system (in degrees, minutes, and seconds) into its decimal equivalent (in degrees).

[→D.MS] : Converts an angle in the decimal system (in degrees) into its sexagesimal equivalent (in degrees, minutes, and seconds).



Example 1:

To convert 12°39′18″ into its decimal equivalent

12.3918 [→DEG] [=]

```
                12. 655
```

Example 2:

To convert 123.678° into its sexagesimal equivalent

123.678 [2ndF] [→D.MS] [=]

```
                123. 40408
```

- Time calculations

The EL-5150 can also perform time calculations using the above angular conversion function.

Example 3:

3 hours 30 minutes 45 seconds
+) 6 hours 45 minutes 36 seconds
(total?)

`(` 3.3045 `→DEG` `+` 6.4536 `→DEG` `)` `2ndF` `→D.MS` `=`

```
                              10. 1621
```

(10 hours 16 minutes 21 seconds)

Other Functions

- Fraction (FRAC)

The FRAC function is used to display the fraction part of a number.

Example:

To solve for the decimal fraction part of the result of division 58 ÷ 8

`2ndF` `FRAC` `(` 58 `÷` 8 `)` `=`

```
                                 0. 25
```

- Integer (INT)

The INT function is used to display of the integer part of a number.

Example:

To solve for the integer part of the result of division 58 ÷ 8

`2ndF` `INT` `(` 58 `÷` 8 `)` `=`

```
                                    7.
```

- Absolute value (ABS)

The ABS function is used to determine the absolute value of a number.

Example:

To solve for the absolute value of log 0.75

`2ndF` `ABS` `(` `LOG` 0.75 `)` `=`

```
                        0. 124938737
```

Playback Function

The playback function recalls the most recent expression. This is useful when you wish to confirm or correct your last calculation. In particular, this function is useful in finding the location of an error which may occur during the execution of a calculation, and thus increases efficiency in error processing.

Example 1:

To confirm the expression entered in memory

`ON/C` 5 `÷` 3 `=` (the display below is in the floating decimal point system)

```
                    1. 666666667
```

`PB`

```
5 ÷ 3 =
```

Cursor blinks

Upon pressing the `PB` (Playback) key, a portion of your orginal input will appear in the display so that you may check or edit it.

If the expression is longer than the display, press `PB` again to obtain the remainder of your input. (Program correction and editing will be detailed in Chapter 3.)

Example 2:

To find the location of an error in calculation (in this example, 0 is erroneously used as divisor instead of 3)

5 `÷` 0 `+` 3 `=`

```
ERROR  2
```

Eroror code (see APPENDIX D)

`PB`

```
5 ÷ 0 + 3 =
```

[◄]

```
5÷0+3=
```

3 [=]

```
                 4.666666667
```

The expression may also be changed using the [INS] key (to insert characters) and [DEL] key (to delete characters).

NOTE:

When a lengthy expression such as [(] 132 [×] [COS] 32 [+] 145 [×] [COS] 67 [)] [→POL] [(] 132 [×] [SIN] 32 [+] 145 [×] [SIN] 67 [=] is entered in memory, the playback function causes the expression to be displayed by dividing it into sections, each of which falls within the 24-digit capacity of the LCD.

[PB]

```
                                 →
(132×COS 32+145×COS 67)
```

[PB]

```
←                                →
→POL (132×SIN 32+145×
```

[PB]

```
←
SIN 67=
```

[PB]

```
                                 →
(132×COS 32+145×COS 67)
```

In the above example, the "←" indicator indicates that the contents of the display exist at the left of the number or data now being displayed. Likewise, the "→" indicator indicates that the number or data yet to be displayed exists at the right of the screen.

Answer Memory Function

Calculation results obtained with any of the operation execution keys ([=] , [M+] , [2ndF] [M+] , [⇒M] , [STO] [A] ~ [STO] [Z] , [→BIN] , [→OCT] , [→HEX] , [→DEC]) are stored in the answer memory. The value currently held in the answer memory (i.e., the result of the last computation) can be inserted into any position of the next algebraic expression by using the [ANS] key.

Example:

To calculate 12×5 ÷ 6.25 + 24×3 ÷ 6.25 = where 6.25 is the result of division 50 ÷ 8 = previously perfomed

[ON/C] 50 [÷] 8 [=]

```
                                   6. 25
```

(automatically stored in memory)

12 [×] 5 [÷] [2ndF] [ANS]

```
12×5÷6. 25_
```

Recalled from answer memory

[+] 24 [×] 3 [÷] [2ndF] [ANS]

```
12×5÷6. 25+24×3÷6. 25_
```

Recalled from answer memory

[=]

```
                                  21. 12
```

- While the value of the answer memory may be recalled as many times as required, it will be updated whenever an operation is executed with any of the operation execution keys. If an error exists in the result of a calculation, the value of the answer memory will remain unchanged. It will also be updated when a program stored in the AER mode is executed.

- The contents of the answer memory will not be cleared by $\boxed{\text{ON/C}}$ or $\boxed{\text{2ndF}}$ $\boxed{\text{CA}}$ key operation or by power off operation.

Continuous Calculation & Modify Functions

Continuous Calculation Function

Like the answer memory function, the continuous calculation function allows you to use the result of the calculation last performed for the calculation to be next performed.

Example:

To solve for 3 + 4 = and then multiply the calculation result by 5.

`ON/C` 3 `+` 4 `=`

```
                                          7.
```

`×` 5

```
 7. ×5_
```

(multiply command is input following the result of addition)

`=`

```
                                         35.
```

NOTE:

The difference of this function from the answer memory function is that the result of the last calculation can be used only at the beginning of the next calculation.

Modify Function

The modify function causes the internal result of a calculation stored in memory when used in subsequent calculations, to be in agreement with the format of the result of the calculation in the display.
With the EL-5150, the result of a calculation is obtained to the accuracy of up to 12 digits for mantissa, while all the internally executed calculations are in the exponential form ($A \times 10^{B}$). The results of all the internal calculations are displayed on the LCD after being converted into the form designated by the display system (FIX, SCI, or ENG) and the number of decimal positions to be fixed (TAB). So, the use of this modify function allows you to use the calculation result in the display without change, for the next calculation to be performed. This function is very useful when you must perform calculations with the significant digits of a number taken into account as in testing or processing the results of experiments.

Example:

To solve for the result of 5 ÷ 9 = and then multiply the calculation result by 9

[FSE] (to display the FIX indicator)

[TAB] 1 (to fix the number of decimal positions to 1)

- Normal calculation

5 [÷] 9 [=]

```
                    FIX
                                   0. 6
```

[×]

```
                    FIX
5. 6 E −0 1×_
```

result of internal calculation

9 $\boxed{=}$

```
                    FIX
                                  5. 0
```

NOTE:
In a continuous calculation like this example, the value in the display is not used for the calculation. Instead, the value stored in memory is used.

- Calculation with modify function

5 $\boxed{\div}$ 9 $\boxed{=}$ $\boxed{\text{2ndF}}$ $\boxed{\text{MDF}}$

```
                    FIX
                                  0. 6
```

$\boxed{\times}$

```
                    FIX
0. 6×_
```

9 $\boxed{=}$

```
                    FIX
                                  5. 4
```

Memory Calculations

The EL-5150 has 26 memories; one used as an independently accessible memory or store memory and 25 as store memories.

Independently Accessible Memory (M)

- How to use memory

Data movement in and out of the memory is effected by the following three memory control keys:

`⇒M` : Stores the result of a calculation in memory.
`RM` : Recalls the memory contents.
`M+` : Adds the results of a calculation to the memory contents.
`2ndF` `M+` : Subtracts the results of a calculation from the memory contents.

- Application examples of memory

Before you start a memory calculation, you must press either the `ON/C` and `⇒M` keys to clear the memory contents or the `⇒M` key to enter the initial data in the memory.

Example 1:

`ON/C` `⇒M` `FSE` (press until FIX, SCI, and ENG indicators disappear)

```
                                        0.
```

(Memory clear)

$$\begin{array}{rl} 23 + 45 + 78 = & \ldots (1) \\ -52 - 31 + 43 = & \ldots (2) \\ +\,)\ 64 + 73 - 12 = & \ldots (3) \\ \hline \text{(total)} \qquad & \ldots (4) \end{array}$$

23 `+` 45 `+` 78 `M+`

```
                                      146.
```

Answer for (1)

[(−)] 52 [−] 31 [+] 43 [M+]

```
                                    −4 0.
```

Answer for (2)

64 [+] 73 [−] 12 [M+]

```
                                    1 2 5.
```

Answer for (3)

[RM]

```
                                    2 3 1.
```

Total (4)

Example 2:

24 × 13 = ... (1)
+) 56 ÷ 7 = ... (2)
−) 32 × 4 = ... (3)
(total) ... (4)

24 [×] 13 [⇒M]

```
                                    3 1 2.
```

Answer for (1)

56 [÷] 7 [M+]

```
                                        8.
```

Answer for (2)

32 [×] 4 [2ndF] [M+]

```
                                    1 2 8.
```

Answer for (3)

[RM]

```
                                    1 9 2.
```

Total (4)

Example 3:

$24 \div \underline{(7\times3)} = \ldots (1)$

$\underline{(7\times3)}\ \times 5 = \ldots. (2)$

7 $\boxed{\times}$ 3 $\boxed{\Rightarrow M}$

```
                    21.
```

24 $\boxed{\div}$ $\boxed{RM}$ $\boxed{=}$

```
          1.142857143
```

Answer for (1)

$\boxed{RM}$ $\boxed{\times}$ 5 $\boxed{=}$

```
                   105.
```

Answer for (2)

In this example, the result of multiplication 7×3 in calculation (1) is first stored in memory and is then recalled to use it as a constant for calculations (1) and (2).

NOTE:

The equals key need not be pressed before $\boxed{\Rightarrow M}$, $\boxed{M+}$, and $\boxed{2ndF}$ $\boxed{M+}$ as these keys also function as the equals key.

Store Memories

- How to use memories

Data movement in and out of each of the 26 store memories is effected by the following two memory control keys and 26 memory designation keys A through Z.

STO : Clears the contents of the designated memory and stores the number in the display or the result of a calculation in the memory.

RCL : Functions the same as RM key.

- Application example of store memories

Example:

To solve for $C=\frac{AB}{(A+B)}$ with $A=\frac{(12+6)}{3}$ and $B=\frac{6}{(12-8)}$

(12 + 6) ÷ 3 STO A

```
                                        6.
```

Answer for (A)

6 ÷ (12 − 8) STO B

```
                                      1. 5
```

Answer for (B)

AB ÷ (A + B) =

```
                                      1. 2
```

Answer for (C)

NOTE:

Multiply command "X" may be omitted for multiplication between store memories (e.g., A×B) or for multiplication when a store memory is a multiplier (e.g., 3×A, 5×B).

- Use of store memories in expressions

With the EL-5150, the initial capacity of each memory to

store the result of a calculation is 12 digits max. for mantissa and 2 digits max. for exponent.
Any of the $\boxed{A}$ through $\boxed{Z}$ keys may be entered in an expression to use the contents of the designated memory in the expression. Any of the $\boxed{A}$ through $\boxed{Z}$ keys preceded by the $\boxed{RCL}$ key may also be used to display the contents of the designated memory and write them into the expression for calculation.

Example:

To store the result of division 4 ÷ 3 into memory A and then perform the following calculations.

4 $\boxed{\div}$ 3 $\boxed{STO}$ $\boxed{A}$

```
                    1. 333333333
```

① To use an expression written directly with $\boxed{A}$ key.

$\boxed{FSE}$ (to display FIX indicator)

$\boxed{TAB}$ 2 (to designate the fraction part as 2 digits)

2 $\boxed{A}$ $\boxed{\times}$ 3 $\boxed{=}$

```
               FIX
                          8. 00
```

② To use an expression written with $\boxed{RCL}$ and $\boxed{A}$ keys.

2 $\boxed{\times}$ $\boxed{RCL}$ $\boxed{A}$ $\boxed{\times}$ 3 $\boxed{=}$

```
               FIX
                          7. 98
```

In the example ① above, all the contents of memory A (12-digit mantissa and 2-digit exponent) are used, whereas in the example ②, only the internal digits of memory A specified by FIX, TAB = 2 are used for calculation.

NOTE:

1. Store memory M shares the same memory area as the independently accessible memory.
2. The result of a calculation cannot be automatically added to or subtracted from memories A through Z except M. A key sequence such as the one shown below would have to be used if the calculation result 5 is to be added to or subtracted from, for example, memory A:
   5 + [A] [STO] [A]
3. Store memory Z is used to store the results of calculations such as conversions of coordinates, [→POL], and [→REC].
4. Memories A through T can also be used in the STAT mode. Memories U through Z are used to store the statistics.
5. Remember that [RCL] does not carry all internal digits into a calculation if [TAB] is used (see the last example). To retain internal digits, enter the letter (memory designation key) without [RCL].

Binary, Octal, & Hexadecimal Number Calculations

The EL-5150 can perform conversions between any two of decimal, binary, octal, and hexadecimal numbers, and also perform four basic arithmetic operations on numbers expressed in these number systems. Decimal fractions are only possible in the DEC mode.

Number System Modes

To perform conversions between any two of decimal, binary, octal, and hexadecimal numbers, the calculator must be set in one of the following number system modes as applicable, with the Mode Selector switch in the COMP position.

2ndF →BIN : Binary Number System (BIN) Mode.

- Displays 16-digit binary numbers.
- Converts the number in the display into its binary equivalent. When these two keys are pressed, the **BIN** indicator appears at the upper part of the display.
- If an expression is in the display, the calculator performs the calculation of the expression and converts the calculation result into a binary number.
- In this mode, only 0 and 1 keys can be used. The other number keys and decimal point key thus become inoperative.

2ndF →OCT : Octal Number System (OCT) Mode

- Displays 10-digit octal numbers.
- Converts the number in the display into its octal equivalent. When these two keys are pressed, the **OCT** indicator appears at the upper part of the display.
- If an expression is in the display, the calculator performs the calculation of the expression and converts the calculation

result into an octal number.

- In this mode, only 0 through 7 keys can be used. The other number keys and decimal point key thus become inoperative.

2ndF →HEX : Hexadecimal Number System (HEX) Mode

- Displays 10-digit hexadecimal numbers.
- Converts the number in the display into its hexadecimal equivalent. When these two keys are pressed, the HEX indicator appears at the upper part of the display.
- If an expression is in the display, the calculator performs the calculation of the expression and converts the calculation result in a hexadecimal number.
- In this mode, numeral keys 0 through 9 and hexadecimal number keys A through F (Y^x , LOG , LN , x^2 , √ , π) can be used. The decimal point key alone thus becomes inoperative.

2ndF →DEC : Decimal Number System (DEC) Mode

- Converts the number in the display into its decimal equivalent. When these two keys are pressed, no decimal number system indicator appears in the display. Since the calculator normally uses this number system, the absence of any number system mode means that the unit is in the decimal number system mode.
- If an expression is in the display, the calculator performs the calculation of the expression and converts the calculation result into a decimal number.
- In this mode, numeral keys 0 through 9 are used to perform four basic arithmetic operations and scientific calculations.

Cross-reference table for four basic notations

Decimal	Binary	Octal	Hexadecimal
0	0	0	0
1	1	1	1
2	10	2	2
3	11	3	3
4	100	4	4
5	101	5	5
6	110	6	6
7	111	7	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F
16	10000	20	10
17	10001	21	11
18	10010	22	12
19	10011	23	13
20	10100	24	14
:	:	:	:

Conversions of Binary, Octal, Decimal, & Hexadecimal Numbers

Example 1:

To convert decimal number 19 into its binary equivalent (10011 from cross-reference table)

ON/C 2ndF →DEC 19 (Decimal number)

```
1 9 _
```

2ndF →BIN (Dec to Bin)

```
                         BIN
            0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 1
```

Example 2:

To convert hexadecimal number 2BC into its decimal equivalent.

ON/C 2ndF →HEX 2 B C (Hexadecimal number)

```
                                          HEX
 2 B C _
```

NOTE:

Use the hexadecimal number keys Y^x , LOG , LN , x^2 , √ , and π to enter **A**, **B**, **C**, **D**, **E**, and **F** in the HEX mode.

2ndF →DEC (Hex to Dec)

```
                                      7 0 0 .
```

Example 3:

To convert octal number 52 into its hexadecimal equivalent

2ndF →OCT 52 (octal number)

```
                                        OCT
 5 2 _
```

2ndF →HEX (Oct to Hex)

```
                                          HEX
                                  0 0 0 0 0 0 0 0 2 A
```

Example 4:

To convert binary number 101111 into its decimal, hexadecimal, and octal equivalents respectively

2ndF →BIN 101111 (Binary number)

```
                                      BIN
 1 0 1 1 1 1 _
```

2ndF →DEC (Bin to Dec)

```
                                        4 7 .
```

2ndF →HEX (Bin to Hex)

```
                                HEX
                         000000002F
```

2ndF →OCT (Bin to Oct)

```
                                OCT
                         0000000057
```

Example 5:

To convert a decimal number with a fraction part into its binary, octal, or hexadecimal equivalent

2ndF →DEC 12.34 2ndF →HEX

```
                                HEX
                         000000000C
```

As shown in the above example, the fraction part (0.34) is truncated and only the integer part (12) is converted into its hexadecimal equivalent.

Binary, Octal, & Hexadecimal Number Calculations

With the EL-5150, four basic arithmetic operations (add, subtract, multiply, and divide) and memory calculations can be performed in the BIN, OCT, and HEX modes just the same as in the normal DEC mode. (In other than the DEC mode, scientific functions cannot be perfomed.)

- BIN mode

Example 1:

1011 + 1110 =

ON/C 2ndF →BIN 1011 + 1110 =

```
                                BIN
                   0000000000011001
```

Example 2:

(1010 − 100) × 11 =

[(] 1010 [−] 100 [)] [×] 11 [=]

```
                    BIN
 0000000000010010
```

- OCT mode

Example 1:

5 + 7 =

[ON/C] [2ndF] [→OCT] 5 [+] 7 [=]

```
      OCT
 0000000014
```

Example 2:

32 ÷ 2 =

32 [÷] 2 [=]

```
      OCT
 0000000015
```

- HEX mode

Example 1:

2FF − 25 =

[ON/C] [2ndF] [→HEX] 2**FF** [−] 25 [=]

```
      HEX
 00000002DA
```

Example 2:

(2000 − 1**FC**) ÷ 2 =

[(] 2000 [−] 1**FC** [)] [÷] 2 [=]

```
      HEX
 0000000F02
```

- Mixed calculations

Example 1:

To add decimal number 512 to hexadecimal number 1**FFF** and convert the calculation result into a binary number

$\boxed{\text{ON/C}}$ $\boxed{\text{2ndF}}$ $\boxed{\text{→DEC}}$ 512 $\boxed{\text{2ndF}}$ $\boxed{\text{→HEX}}$ $\boxed{+}$ 1**FFF** $\boxed{\text{2ndF}}$ $\boxed{\text{→BIN}}$

```
                         BIN
0 0 1 0 0 0 0 1 1 1 1 1 1 1 1 1
```

Example 2:

2FEC − 2C9E = ... (1)
+) 2000 − 1901 = ... (2)
Total (decimal number) ... (3)

$\boxed{\text{ON/C}}$ $\boxed{\Rightarrow\text{M}}$ $\boxed{\text{2ndF}}$ $\boxed{\text{→HEX}}$ 2**FEC** $\boxed{-}$ 2**C**9**E** $\boxed{\text{M+}}$

```
          HEX
0 0 0 0 0 0 0 3 4 E
```

Answer for (1)

2000 $\boxed{-}$ 1901 $\boxed{\text{M+}}$

```
          HEX
0 0 0 0 0 0 0 6 F F
```

Answer for (2)

$\boxed{\text{RM}}$ $\boxed{\text{2ndF}}$ $\boxed{\text{→DEC}}$

```
2 6 3 7 .
```

Answer for (3)

NOTE:

In binary, octal, or hexadecimal number calculations, if the result or intermediate result of a calculation turns to be a number with a fraction part, the result is displayed with its fraction part truncated.

Example:

$\boxed{\text{2ndF}}$ $\boxed{\text{→OCT}}$ 5 $\boxed{\div}$ 2 $\boxed{=}$

```
      OCT
0 0 0 0 0 0 0 0 0 2
```

In the BIN, OCT, or HEX mode, a negative number is displayed as a complement corresponding to the designated number system.

Example:

2ndF →DEC (−) 1

```
−1_
```

2ndF →BIN

```
                                  BIN
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

(two's complement)

2ndF →OCT

```
      OCT
7 7 7 7 7 7 7 7 7 7
```

(eight's complement)

2ndF →HEX

```
        HEX
F F F F F F F F F F
```

(16's complement)

In the BIN, OCT, or HEX mode, a negative number is entered using the NEG ((−)) key.

Example:

To enter negative hexadecimal number 2

2ndF →HEX NEG 2

```
                                   HEX
NEG  2_
```

=

```
        HEX
F F F F F F F F F E
```

Logical Operations

The EL-5150 can perform logical AND, OR, XOR (exclusive OR), XNOR (exclusive NOR), and NOT operations on binary, octal, and hexadecimal numbers.
To enter logical operators, NOT, AND, OR, XOR, and XNOR, use the [FSE], [TAB], [→DEG], [→POL], and [nCr] keys, respectively. The function printed at the right above each of these keys will be entered.

The truth tables of the logical operations are as shown below.

A	B	A AND B	A OR B	A XOR B	A XNOR B
0	0	0	0	0	1
1	0	0	1	1	0
0	1	0	1	1	0
1	1	1	1	0	1

A	NOT A
0	1
1	0

Example 1:

AND operation of binary numbers 1101 and 111

[ON/C] [2ndF] [→BIN] 1101 [AND] 111 [=]

```
                                    BIN
                  0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1
```

Example 2:

OR operation of hexadecimal numbers 5B and F3

[ON/C] [2ndF] [→HEX] 5B [OR] F3 [=]

```
                HEX
0 0 0 0 0 0 0 0 F B
```

Example 3:

NOT operation of binary number 101011

[ON/C] [2ndF] [→BIN] [NOT] 101011 [=]

```
                BIN
1 1 1 1 1 1 1 1 1 1 0 1 0 1 0 0
```

Example 4:

Exclusive-OR operation of octal numbers 26 and 54

[ON/C] [2ndF] [→OCT] 26 [XOR] 54 [=]

```
      OCT
0 0 0 0 0 0 0 0 7 2
```

Example 5:

Exclusive-NOR operation of hexadecimal numbers A5 and 2F

[ON/C] [2ndF] [→HEX] A5 [XNOR] 2F [=]

```
        HEX
F F F F F F F F 7 5
```

Example 6:

OR operation of hexadecimal number 8E and binary number 11101

[ON/C] [2ndF] [→HEX] 8E [2ndF] [→BIN] [OR] 11101 [=]

```
                BIN
0 0 0 0 0 0 0 0 1 0 0 1 1 1 1 1
```

Example 7:

AND operation of hexadecimal number F5 and the result of OR operation of hexadecimal numbers 84 and 7E

$\boxed{\text{ON/C}}$ $\boxed{\text{2ndF}}$ $\boxed{\to\text{HEX}}$ $\boxed{(}$ 84 $\boxed{\text{OR}}$ 7E $\boxed{)}$ $\boxed{\text{AND}}$ F5 $\boxed{=}$

```
                                    HEX
                       0 0 0 0 0 0 0 0 F 4
```

Statistical Calculations

Statistical Calculation (STAT) Mode

- Before performing a statistical calculation, you must place the calculator in the STAT mode. To do so, press the 2ndF and STAT keys with the Mode Selector switch in the COMP position, and the STAT indicator will appear at the upper part of the display.
To release the calculator from the STAT mode, press the 2ndF and STAT keys a second time.

- Remember that in the STAT mode, those keys not used for statistical calculations become inoperative. Examples of such keys are: RM , ⇒M , M+ , 2ndF M+ , U – Z , COMP , TITLE , ↓ , ↑ . Those keys used in the AER mode are also inoperative. In the STAT mode, binary, octal, and hexadecimal number calculations and conversions of coordinates cannot be effected.

- The results of statistical calculations cannot be cleared with the ON/C . Use the 2ndF and CA keys to clear the statistics stored in memories U through Z before you start another statistical calculation.

- Even after the results of a statistical calculation have been obtained, additional information can be entered and the statistical calculation can be performed continuously on additional data entry.

- The following statistics obtained from a statistical calculation are stored in memories U through Z and are retained in memory even after the calculator is released from the STAT mode.

Memory	Z	Y	X	W	V	U
Contents	n	Σx	Σx^2	Σxy	Σy	Σy^2

- Memories A through T may also be used in the STAT mode and their contents will not be affected by any statistical calculations.

Single-variable Statistical Calculation

- Statistics obtainable from calculation

(1) n : Number of samples
(2) Σx : Sum total of samples
(3) Σx^2: Sum of squares of samples
(4) $\bar{x}$: Mean value of samples

$$\bar{x}=\frac{\Sigma x}{n}$$

(5) Sx : Standard deviation with population parameter taken as "n-1".

$$Sx=\sqrt{\frac{\Sigma x^2-n\bar{x}^2}{n-1}}$$

(Used to estimate the standard deviation of a population from the sample data extracted from that population.)

(6) σx : Standard deviation with population parameter taken as "n".

$$\sigma x=\sqrt{\frac{\Sigma x^2-n\bar{x}^2}{n}}$$

(Used when all populations are taken as sample data or when finding the standard deviation of a population with samples taken as that population.)

- Data input for calculation

Data for single-variable statistic calculations are entered by the following key operations:

(1) Data $\boxed{\text{DATA}}$ (used to enter data one by one)
(2) Data $\boxed{\times}$ Frequency $\boxed{\text{DATA}}$ (used to enter two or more of the same data)

Data can be entered in the form of an algebraic expression. However, it must be parenthesized when the "+", "−", "×" or "÷" command is used.

Examples:

(5 + 4×3) DATA ………………. Frequency of data is 1.
(SIN3 + LN2)×5 DATA ……. Frequency of data is 5.

In the above examples, if the expression was not parenthesized, 5+ and SIN3+ would be ignored, and the same results would be returned as in key operations 4×3 DATA and LN2×5 DATA .
Frequency of data entered in the form of an expression must also be parenthesized.

Example:

$$10 \; \boxed{\times} \; \underbrace{\boxed{(} \; 3 \; \boxed{+} \; 2 \; \boxed{)}}_{\text{must be parenthesized.}} \; \boxed{\text{DATA}}$$

- **Calculation**

Example:
To solve for the mean value and standard deviation of the marks in an examination of randomly selected 35 students shown in the table below.

Data No.	Marks in exam	No. of students	Data No.	Marks in exam	No. of students
1	30	1	5	70	8
2	40	1	6	80	9
3	50	4	7	90	5
4	60	5	8	100	2

2ndF STAT (STAT mode is set)

2ndF CA

```
                                   STAT
                                  0.
```

(STAT indicator lights)

- Data entries

30 DATA 40 DATA

```
                                   STAT
                                  2.
```

(Number of samples is displayed)

50 [×] 4 [DATA] 60 [×] 5 [DATA]

```
                                STAT
                             11.
```

70 [×] 8 [DATA] 80 [×] 9 [DATA]

```
                                STAT
                             28.
```

90 [×] 5 [DATA] 100 [×] 2 [DATA]

```
                                STAT
                             35.
```

- Mean value

[2ndF] [$\bar{x}$]

```
                                STAT
                     71.42857143
```

- Standard deviation

[2ndF] [Sx]

```
                                STAT
                     16.47508942
```

[2ndF] [σx]

```
                                STAT
                     16.23802542
```

- Number of samples

[2ndF] [n]

```
                                STAT
                             35.
```

- Sum total of samples

[2ndF] [Σx]

```
                                STAT
                           2500.
```

- Sum of squares of samples

`2ndF` `Σx²`

```
                         STAT
               187800.
```

`2ndF` `STAT` (STAT mode is released)

```
                    0.
```

(STAT indicator goes off)

NOTE:

1. After all the data have been entered, statistics such as mean value, standard deviation, etc. may be obtained in any desired order.
2. After a mean value, standard deviation, or any other statistic has been obtained as an intermediate result, more data can be entered and statistical calculations can be performed continuously on additional data entry.
3. The `DATA` key may be pressed consecutively to enter two or more of the same data instead of key operation; `X` Frequency `DATA` .

● Data entry correction

If an erroneous data has been entered, the incorrect entry can be corrected using the `CD` key.

Example:
To correct the marks of data No. 3 erroneously entered as 55 instead of 50 in the above example

`2ndF` `STAT` `2ndF` `CA`

```
                     STAT
                    0.
```

- Data entries

30 `DATA`

```
                     STAT
                    1.
```

40 [DATA]

```
                                   STAT
                                 2.
```

55 [×] 4 [DATA]

```
                                   STAT
                                 6.
```

(Incorrect data is input)

- Data correction

55 [×] 4 [CD]

```
                                   STAT
                                 2.
```

(Incorrect data is cleared)

50 [×] 4 [DATA]

```
                                   STAT
                                 6.
```

(Correct data is input)

60 [×] 5 [DATA]

```
                                   STAT
                               1 1.
```

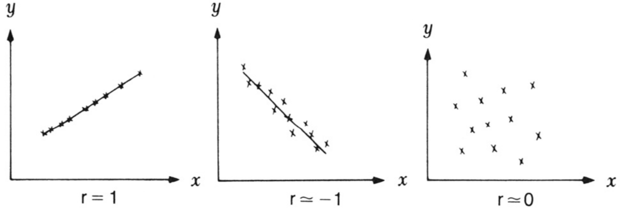
NOTE:
An erroneous data entry before pressing the [DATA] key can be cleared by the [ON/C] key. The correct data may then be entered.

Two-variable Statistical Calculation

• Statistics obtainable from calculation

Statistics for both x and y such as n, Σx, $\bar{x}$, Σx^2, Sx, σx, and Σy, Σy^2, $\bar{y}$, Sy, σy are the same as those for x in single-variable statistics, except that samples should be identified as x and y respectively. In addition, Σxy (the sum of the product of samples x and y) is obtained in this calculation.

In Linear Regression there are three important values; r, a, and b. The correlation coefficient r shows the quantitative relationship between two variables x and y for a particular sample. The value of r is between −1 and 1. If r equals −1 or 1, all points on the correlation diagram are on a line. The further the value of r is from −1 or 1, the less the points are massing about the line. The closer the value of r to 0, the less reliable is the correlation. If r is more than 0, it shows a positive correlation (y is in proportion to x) and if r is less than 0, it is a negative correlation (y is in inverse proportion to x).



The equation for the straight line is $y = a + bx$. The point at which the line crosses the y axis is a. The slope is b.

r : Correlation coefficient

$$r = \frac{Sxy}{\sqrt{Sxx \cdot Syy}}$$

a : $a = \bar{y} - b\bar{x}$

b : $b = \frac{Sxy}{Sxx}$

Coefficient of linear regression equation $y = a + bx$

x′ : Estimated value (the value of x is estimated from that of y.) $x' = \frac{y - a}{b}$

y′ : Estimated value (the value of y is estimated from that of x.) $y' = a + bx$

$$\left(\begin{array}{l} Sxx=\Sigma x^2-\dfrac{(\Sigma x)^2}{n} \\ Syy=\Sigma y^2-\dfrac{(\Sigma y)^2}{n} \\ Sxy=\Sigma xy-\dfrac{\Sigma x\cdot\Sigma y}{n} \end{array}\right)$$

- **Data input for calculation**

Data for two-variable statistic calculations are entered by the following operations.

(1) Data "x" $\boxed{(x,y)}$ Data "y" $\boxed{\text{DATA}}$ (used to enter data one by one)

(2) Data " x" $\boxed{(x,y)}$ Data "y" $\boxed{\times}$ Frequency $\boxed{\text{DATA}}$ (used to enter two or more of the same data)

Example:

85 $\boxed{(x,y)}$ 79 $\boxed{\text{DATA}}$	Frequency of data is 1.
51 $\boxed{(x,y)}$ 73×5 $\boxed{\text{DATA}}$	Frequency of data is 5.

- **Calculation**

Example:

The following table shows the marks in Math and English of six students respectively. From this data, solve for the coefficients a and b of linear regression $y = a + bx$ and correlation coefficient r. Then extimate the mark in English of a student who would get 90 marks for Math and the mark in Math of a student who would get 80 marks for English.

Student No. n	Mark in Math. x	Mark in English y
1	82	79
2	53	50
3	61	87
4	74	96
5	51	73
6	51	73

`2ndF` `STAT` `2ndF` `CA`

82 `(x,y)` 79 `DATA` 53 `(x,y)` 50 `DATA`

61 `(x,y)` 87 `DATA` 74 `(x,y)` 96 `DATA`

51 `(x,y)` 73 `×` 2 `DATA`

```
                                        STAT
                                      6.
```

`2ndF` `(a)`

```
                                        STAT
                        34.261904 76
```

`2ndF` `(b)`

```
                                        STAT
                        0.678571429
```

`2ndF` `(r)`

```
                                        STAT
                        0.571587901
```

(this is a moderately reliable correlation.)

90 `2ndF` `(y′)`

```
                                        STAT
                        95.33333333
```

(Estimated mark in English)

80 `2ndF` `(x′)`

```
                                        STAT
                        67.40350877
```

(Estimated mark in Math)

CHAPTER 3
OPERATIONS IN AER MODE

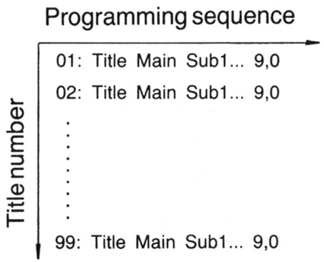
The EL-5150 is provided with a mode called the "Algebraic Expression Reserve (AER)", which is convenient for repetitive calculations. This mode allows you to preprogram calculation procedures (i.e., algebraic expressions) into the calculator in the AER mode so that the calculator may automatically execute calculations on numbers (variables) which you will enter in the COMP mode. The calculator has a programming capacity of 1,454 steps (or 1,454 bytes) for storing programs consisting mainly of algegraic expressions and mathematical formulas. In addition, the calculator can perform conditional expression judgment, looping, and subroutine functions.

How to Use Algebraic Expression Reserve

Configuration of AER

An algebraic expression (or a program) consists of a title and a main routine with or without one or more subroutines.

- Configuration


Programming sequence
Title number
01: Title Main Sub1... 9,0
02: Title Main Sub1... 9,0
99: Title Main Sub1... 9,0

- Input message

Input of title name

```
01 : TITLE   ?
```

Input of main routine

```
M : _
```

Input of subroutine(s)

```
1 : _
```

```
2 : _
```

:

```
0 : _
```

(1) Title

To store a program, first type in the program title name:

- When you slide the MODE Selector switch to the AER position, a message: “01:TITLE?” will appear in the display to prompt you to enter the title of your program. A title name may not necessarily be entered. But it’s better to have one for quick, easy retrieval of the program you want to use later. You may program a maximum of 99 algebraic expressions within the memory capacity of the calculator. A 2-digit title number (01 - 99) will be displayed to the left of the “TITLE?” message.

- Up to 21 characters may be used for a single title. Title characters exceeding 21 characters will be ignored. (Some keys are not usable for program title entry.)

- Pressing the [ENT] key following the entry of title characters causes the program title to be stored in memory. If no program title is needed, press the [ENT] key alone.

(2) Main routine

- When you press the [ENT] key to store the program title, “M:_” will appear in the display. This indicator “M“ informs you that you are going to store a main routine. (The first program line immediately after a program title is automatically assigned to a main routine.)

(3) Subroutine(s)

- In a series of calculation procedures, if you have an expression to be used over and over again, it is advisable to write the expression as a subroutine for execution as the occasion calls for. In this way, you can simplify the calculation procedures.

- If you wish to use a subroutine in a program, press the [SUB :] key after typing in the main routine. The main routine is stored in memory and “ 1 :_ ” indicator

appears in the display to prompt you to enter the subroutine. The indicator " 1 : _ " is the label number of your first subroutine. You can program a maximum of 10 subroutines per main routine.
The calculator sequentially labels all the subroutines to be stored with numbers 1 through 9 and 0 , at the beginning of each subroutine line.

- If your main routine has no subroutine, press the ENT key after typing in the main routine. A message "02: TITLE?" will appear in the display. (The title number may not be "02" depending on the number of programs already stored).

NOTE:

1. The maximum length of an expression that you can write in one program line is 160 steps. Any characters and symbols entered in excess of this capacity are regarded as the 160th step and cause the character or symbol previously entered at that step to be rewritten. So, be sure to program each of your expressions within the capacity of 160 steps per line. If this is not possible, use subroutines.
2. Remember that in the STAT mode, the calculator cannot execute any of the programs you wrote in the AER mode.

Programming Formulas

Programs can easily be written so that when they are run (in COMP mode), they will ask you for values. There are two methods:

(1) Input format I
The f( )= key allows algebraic expressions to be entered in the form of:

f (A ~ Z) = Expression

by designating any of the memories A through Z as variables.

Example:

$f(AB) = A^2 + AB + B^2$

(2) Input format II

The 2ndF VAR function allows lowercase letters (a ~ z), Greek letters (α, β, γ, θ), and numeric characters reduced in size to be entered. The calculator automatically regards all these characters in an expression as variables. Thus, an expression is entered in the form of:

Variables = Expression
└ lowercase letters, Greek letters (α, β, γ, θ), numeric characters reduced in size.

Example:

$c = a^2 + a \times b + b^2$

Characters for Variables

- In the AER mode, the calculator is put in the VAR (Variable Character Input) mode by pressing the 2ndF and VAR keys. The VAR indicator appears in the display. Pressing these two keys a second time causes the calculator to exit from the VAR mode and the VAR indicator to disappear.

- In the VAR mode, the following keys are used to enter:
  A ~ Z : Lowercase letters
  0 ~ 9 : Numeric characters reduced in size
  RCL , RM , ⇒M , M+ : Greek letters (α, β, γ, θ)

- If one or more of these variable characters are used in succession such as "a1", the calculator automatically treats the character(s) as one variable. A maximum of seven variable characters may be used in succession.

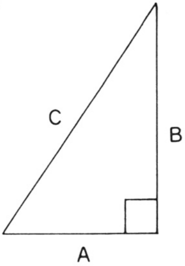
Programming Examples

- Before you start the following programming and calculation examples, push the Reset switch to clear the memory contents. (See page 4 for operation of the Reset switch.)

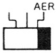
```
ALL CLEAR ? →ENT
```

Check that the above message appears in the display and then press the `ENT` key.

Example 1:
Pythagorean Theorem Program
To solve for the length of hypotenuse C in a right triangle with a given length on each of the other two sides A and B, where $C = \sqrt{A^2 + B^2}$ must be solved for in the form of
$f(AB) = \sqrt{(A^2 + B^2)}$



(1) Programming

Mode:  (AER mode)

```
01 : TITLE ?
```

`2ndF` `P` `Y` `2ndF` `T` `H` `A` `G` `2ndF` `O` `2ndF` `R` `A` `2ndF` `S` (title name is input)

```
01 : PYTHAGORAS_
```

`ENT` (title name is stored)

```
M : _
```

`f( )=` `A` `B` `f( )=` `√` `(` `A` `x²` `+`

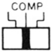
`B` `x²` `)` (main routine is input)

```
M: f (AB) =√(A 2 +B 2 ) _
```

`ENT` (main routine is stored)

```
02:TITLE  ?
```

(2) Program Calculation (where A = 3, B = 4)

Mode:  (COMP mode)

```
                                        0.
```

`TITLE`

```
01:PYTHAGORAS
```

`COMP`

```
A=?
```

(The calculator is asking you for the value of A.)

3 `COMP`

```
B=?
```

(The calculator is asking you for the value of B.)

4 `COMP`

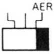
```
ANS  1=                        5.
```

(Length of C is given as Answer 1)

- More than one algebraic expression may be written on a program line by separating them with the space `␣` or comma `,` key. If two expressions are separated by a space, the calculator will execute the expression immediately after the space without displaying the result of the expression immediately before the space. If they are separated by a comma, the calculator will display the result of the preceding expression before proceeding to the following one.

Example 2:
Plotting Program
To solve for f (A) = $3A^2 + 7A + 9$ with the value of A being as 1, 2, 3, ···

(1) Programming

Mode: 

(AER mode)

```
02:TITLE   ?
```

[2ndF] [P] [2ndF] [L] [2ndF] [O] [2ndF] [T]
[ENT]

```
M:_
```

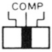
[A] [+] 1 [STO] [A] [,] 3 [A] [x^2] [+]
7 [A] [+] 9

```
M:A+1⇒A, 3A²+7A+9_
```

[ENT]

```
03:TITLE   ?
```

(2) Program Execution

Mode: 

(COMP mode)

```
                              0.
```

[TITLE]

```
02:PLOT
```

0 [STO] [A]

```
                                  0.
```

[COMP]

```
ANS  1=                           1.
```

(A = 1)

[COMP]

```
ANS  2=                          19.
```

(f(1))

[COMP]

```
ANS  1=                           2.
```

(A = 2)

[COMP]

```
ANS  2=                          35.
```

(f(2))

NOTE:

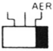
In the above example, the number displayed to the right of "ANS" indicates that the answer is that of the 1st or 2nd expression separated by a comma.

Example 3:

Cosine Rule Program

$c = \sqrt{a^2 + b^2 - 2ab\cos\theta}$

(1) Programming

Mode: 

(AER mode)

```
03:TITLE  ?
```

[C] [2ndF] [O] [2ndF] [S] [I] [2ndF] [N] [E]

[ENT]

```
M:_
```

`2ndF` `VAR` `C` `=` `√` `(` `A` `x²`

`+` `B` `x²` `−` `2ndF` `VAR` 2 `2ndF` `VAR`

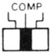
`A` `×` `B` `COS` `θ` `)`

```
                                    VAR
M: c=√(a²+b²−2a×bCOS  θ) _
```

`ENT`

```
04:TITLE  ?
```

(2) Program execution (where a = 4, b = 7, θ = 60°)

Mode:  (COMP mode)

```
                              0.
```

`TITLE`

```
03:COSINE
```

`2ndF` `DRG` (Press until DEG is designated)

`COMP`

```
          DEG
a=?
```

4 `COMP`

```
          DEG
b=?
```

7 `COMP`

```
          DEG
θ=?
```

60 `COMP`

```
          DEG
c=              6.0827625 3
```

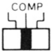
(length of C)

Variable data Check by Playback Function

When executing any of the programs (algebraic expressions) stored in memory, the calculator holds the number of value entered as a variable until the next input. To confirm the number already stored in memory, press the [PB] key and the number will be recalled to the display from memory.

Example:
Cosine Rule Program

$$c = \sqrt{a^2 + b^2 - 2ab\cos\theta}$$

Mode: 

(COMP mode)

[TITLE]

```
03:COSINE
```

[COMP]

```
a = ?
```

4 [COMP]

```
b = ?
```

7 [COMP]

```
θ = ?
```

60 [COMP]

```
c =                6. 08276253
```

[COMP]

```
a = ?
```

PB

```
a = 4 .
```

Blinking cursol (The number stored in variable a is displayed.)

COMP

```
b = ?
```

Search Functions

- Title search

This function allows you to search the title names of the expressions stored in memory one by one (in ascending order of title numbers) at each depression of the TITLE key.

To execute any of the programs stored, you must perform the title search operation with the calculator in the COMP mode and then press the COMP key when the desired title is recalled on the display.

To correct any of the stored programs, you must perform the title search operation with the calculator in the AER mode, and then press the ↓ key to display the program contents when the desired title is recalled on the display.

NOTE:

1. The TITLE key causes title names to be displayed, commencing with the one last accessed.
2. The TITLE key may be pressed and held down to search title names quickly in ascending order.
3. Title names can be searched in the descending order of title numbers by pressing the 2ndF and TITLE keys. Holding down the TITLE after 2ndF allows quick review of title in descending order.

- Direct search

Enter the first character (or several characters from the beginning) of the title name you want to search and then press the TITLE key. The title names commencing with the designated character string can now be accessed directly.

Example:

To search a program named "COSINE"

C 2ndF O TITLE

```
03:COSINE
```

If none of the programs commencing with characters "CO" exists in memory, the calculator will return the following message to you.

```
NOT FOUND
```

NOTE:

The direct search function is effective only for the alphabetic and numeric characters. If a title name has been entered using function keys such as SIN and COS , such a title name cannot be searched directly even though the key operation: 2ndF S TITLE or C TITLE is performed. A message "NOT FOUND" is also displayed in this case.

Conditional Expression Judgment Function

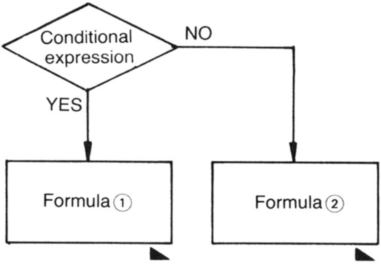
The EL-5150 compares the left side of a conditional expression (in which >, >=, or ≠ sign is used) with its right side, and determines the destination of the calculation to be executed next based on the result of the comparison. If the condition in the conditional expression is satisfied, the calculator executes the calculation or operation enclosed with brackets preceded by –Y→. If not satisifed, the unit executes the calculation or operation enclosed with brackets preceded by –N→.

NOTE:
A conditional expression cannot be used inside the –Y→ [ ] or –N→ [ ] brackets.

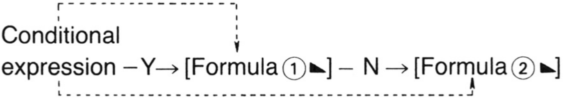
You can write a conditional expression in the following forms:

Left side > Right side	Is left side greater than right side?
Left side ≠ Right side	Is left side unequal to right side?
Left side >= Right side	Is left side equal to or greater than right side?

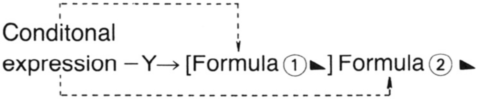
Example 1:
Flowchart of Conditional Judgement Function



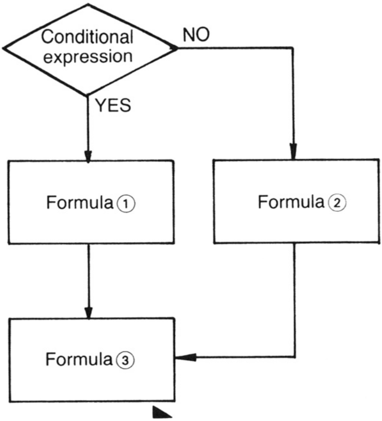
In the conditional expression as shown in the above flowchart, if a given condition is satisfied (if YES), formula ① is executed. If a given condition is unsatisfied (if NO), formula ② is executed. This decision is made using the [-Y→[]] and [-N→[]] keys.


Conditional
expression –Y→ [Formula ①◣] – N → [Formula ②◣]

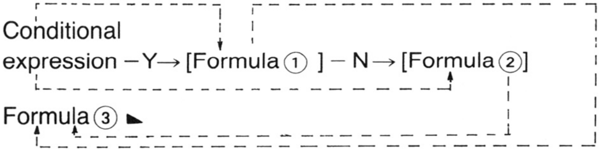
NOTE:
Either of –Y→ [ ] or – N→ [ ] may be omitted from entry as shown below.


Conditonal
expression –Y→ [Formula ①◣] Formula ② ◣

Example 2:
Flowchart of Conditonal Judgement Function



In the conditional expression as shown in the above flowchart,
If YES, formula ③ is executed after formula ①. If NO, formula ③ is executed after formula ②.


Conditional
expression −Y→ [Formula ①] − N→ [Formula ②]
Formula ③ ◣

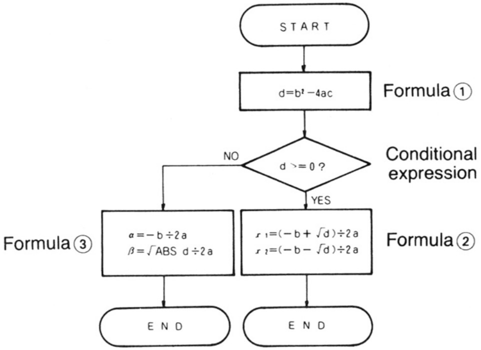
- To terminate a series of calculations, [2ndF] [◣] (Calculation End Command) must be entered after the last formula in the series.

Example 3:
Quadratic equation
Let's solve for $ax^2 + bx + c = 0$, where $a \neq 0$ and a, b, and c are real numbers.
The quadratic equation can be solved by the following formula:

$$x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

With the value of the discriminant $d = b^2 - 4ac$ under $\sqrt{}$, real numbers are solved for if $d \geq 0$, and conjugate imaginary numbers are solved for if $d < 0$.

- Flowchart of expression



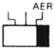
Formula ① is a discriminant.
Conditional expression determines if the value of the discriminant is equal to or greater than 0.
Formula ② solves for real numbers.
Formula ③ solves for imaginary nubmers (where α is the real part and β is the imaginary part).

- Input format of expression

Formula ① Conditional expression – Y→ [Formula ② ◣]
– N → [Formula ③ ◣]

Formula ② to be stored in subroutine
Formula ③ to be stored in subroutine

(1) Programming

Mode: 

(AER mode)

```
04 : TITLE  ?
```

`2ndF` `Q` `2ndF` `U` `A` `D` `2ndF` `R` `A`
`2ndF` `T` `I` `C` `␣` `E` `2ndF` `Q` `2ndF`
`U` `A` `2ndF` `T` `I` `2ndF` `O` `2ndF` `N`
`ENT`

```
M : _
```

`2ndF` 1 `2ndF` `VAR` `D` `2ndF` `>=` `2ndF` `VAR`
0 `2ndF` `-Y→[]` `2ndF` 2 `2ndF` `◣` `2ndF` `-Y→[]` `2ndF`
`-N→[]` `2ndF` 3 `2ndF` `◣` `2ndF` `-N→[]`

```
M : ❶ d >= 0 ▬Y➡ [ ❷ ◣] ▬N➡ [ ❸ ◣] _
```

`SUB :` (main routine is stored)

```
❶ : _
```

`2ndF` `VAR` `D` `=` `B` `x²` `−` `2ndF` `VAR`
4 `2ndF` `VAR` `A` `×` `C`

```
                                              VAR
1 : d=b ² −4 a×c_
```

`SUB :` (Subroutine 1 is stored)

```
2 : _
```

`2ndF` `VAR` `X` 1 `=` `(` `(−)` `B` `+` `√`
`D` `)` `÷` `2ndF` `VAR` 2 `2ndF` `VAR` `A` `,`

```
                                              VAR
2 : χ 1 = (− b+√d) ÷2 a, _
```

`X` 2 `=` `(` `(−)` `B` `−` `√` `D` `)`
`÷` `2ndF` `VAR` 2 `2ndF` `VAR` `A`

```
←                                             VAR
− b+√d )÷2 a,χ 2= (− b −√d) ÷2 a_
```

`SUB :` (Subroutine 2 is stored)

```
3 : _
```

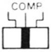
`2ndF` `VAR` `α` `=` `(−)` `B` `÷` `2ndF` `VAR` 2
`2ndF` `VAR` `A` `,` `β` `=` `√` `2ndF` `ABS`
`D` `÷` `2ndF` `VAR` 2 `2ndF` `VAR` `A`

```
                                              VAR
3 : α=−b÷2 a, β=√ABS  d÷2 a_
```

`ENT` (Subroutine 3 is stored, and the program is completed)

```
05 : TITLE  ?
```

(2) Program execution (where a=2, b=−4, c=1)

Mode: 

(COMP mode)

```
                                   0.
```

TITLE

```
04:QUADRATIC EQUATION
```

COMP

```
b=?
```

(−) 4 COMP

```
a=?
```

2 COMP

```
c=?
```

1 COMP

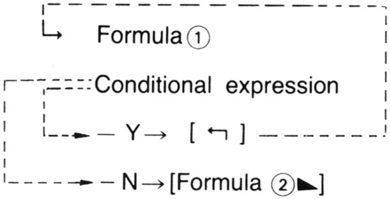
```
x1=             1.70710678 1
```

COMP

```
x2=             0.292893219
```

Looping Function

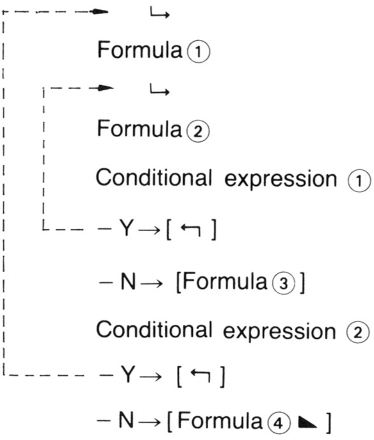
The looping function permits the same calculation or processing to be repeated over and over again. This function is designated in a series of calculation procedures by using two commands: " ↳ " (Return here) and " ↰ " (Return from here to " ↳ " command).
The basic looping format is as shown below.



If YES, execution returns to formula ①, and If NO, formula ② is executed.

NOTE:
Up to 15 loops can be nested.

Example:
Double-looped conditional expressions



NOTE:

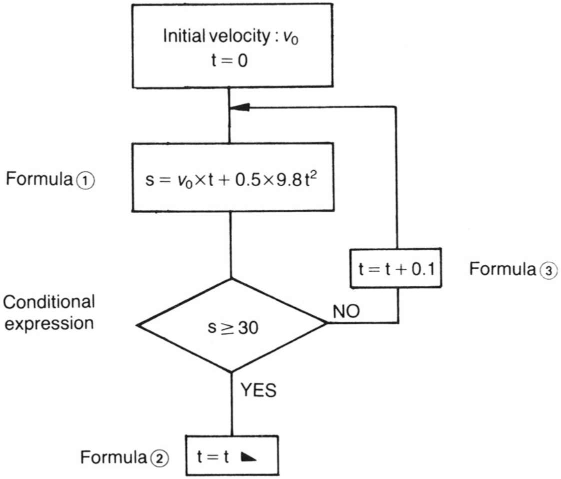
>, >=, ≠, – Y→ [ ], – N→ [ ], ↳ , and ↰ cannot be used in a subroutine.

Let's write a program expression using both the conditional judgement and looping functions.

Example:
Program "DOWN"
To solve for the approximate value of the time when a ball falling from the point 30 meters above the ground at the initial velocity of v_0 (m/s) reaches the ground

Falling distance $s = v_0 \times t + 0.5 \times 9.8t^2$

- Flowchart of expression

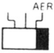


- Input format of expression

↳ Formula ① conditional expession – Y → [Formula ② ◣]

– N → [Formula ③ ↰]

(1)Programming

Mode: 

(AER mode)

05 : TITLE ?

[D] [2ndF] [O] [2ndF] [W] [2ndF] [N]

05 : DOWN_

[ENT]

M : _

[2ndF] [↳] [2ndF] [VAR] [2ndF] [S] [=] [2ndF] [V]
0 [×] [2ndF] [T] [+] [2ndF] [VAR] 0.5 [×] 9.8
[2ndF] [VAR] [2ndF] [T] [x^2] [␣]

M : ↳ s = v_0 × t + 0. 5 × 9. 8 t^2 ␣ _ VAR

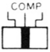
[2ndF] [S] [2ndF] [>=] [2ndF] [VAR] 30 [2ndF] [-Y→[]] [2ndF]
[VAR] [2ndF] [T] [=] [2ndF] [T] [2ndF] [◣] [2ndF] [-Y→[]]
[2ndF] [-N→[]] [2ndF] [T] [=] [2ndF] [T] [+] [2ndF] [VAR]
0.1 [2ndF] [↰] [2ndF] [-N→[]]

←
0 ▬Y➡ [t = t ◣] ▬N➡ [t = t + 0. 1 ↰] _

[ENT]

06 : TITLE ?

(2) Program execution (where $v_0 = 3$, $t = 0$)

Mode: 

(COMP mode)

```
                                 0.
```

TITLE

```
05:DOWN
```

COMP

```
v0 =?
```

3 COMP

```
t =?
```

0 COMP

```
t =                          2. 2
```

(The approximate value is 2.2 seconds.)

Program Correction & Editing

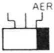
Correction of Title Name Entry

During the input of a program in the AER mode, if you find an error in the title name of the program, press the [◄] or [►] key to move the cursor to the point where an incorrectly entered character exists. Enter the correct character at the point where the cursor blinks.

- The [DEL] key causes the character at the cursor position to be deleted.
- The [2ndF] and [INS] keys cause all the characters at the right of the cursor position to move to the right by one digit. Then the " ⊐ " indicator appears at the cursor position to prompt you to insert the correct character at that position.

Example 1:

To correct the title name erroneously entered during programming to read from "COSSAIN" to "COSSINE"

Mode:  (AER mode)

```
06 : TITLE  ?
```

[C] [2ndF] [O] [2ndF] [S] [2ndF] [S] [A] [I] [2ndF] [N]

```
06 : COSSAIN_
```

[◄] [◄] [◄] [I] [2ndF] [N] [E]

```
06 : COSSINE_
```

(Title name is corrected.)

[ENT]

```
M : _
```

(Title name is stored.)

2ndF VAR C = $\sqrt{\ }$ (A x^2 + B

x^2 − 2ndF VAR 2 2ndF VAR A × B

COS θ)

VAR

M : $c=\sqrt{\ }(a^2+b^2-2a\times b$ COS θ) _

ENT

07 : TITLE ?

- To correct the incorrect title name of the program stored in memory, recall the title of the program by performing the title search operation in the AER mode. The title name can then be corrected in the same manner as in example 1.

Example 2:
To correct the erroneously entered title name of the program stored in memory to read from "COSSINE" to "COSINE"

TITLE

06 : COSSINE

(Title search function.)

▶ ▶ ▶ ▶ DEL

06 : COSINE

(Title name is corrected.)

ENT

M : $c=\sqrt{\ }(a^2+b^2-2a\times b$ COS θ)

(Title name is stored.)

ENT

07 : TITLE ?

In either case, be sure to press the ENT key at the end of the correction.

Correcting Program Contents

- To correct the contents of a program (one or more algebraic expressions) stored in memory, perform the title search operation in the AER mode to recall the title of the program you wish to correct on the display. Then press the ↓ key and the contents of the main routine will be displayed. If the program has any subroutines, press the ↓ key consecutively to display the subroutines. As you did in the title name correction, move the cursor to the point on a program line where you wish to make corrections and then enter character(s) for correction.

- Press the ENT key after you have completed the correction of each main or subroutine line.

NOTE:
Variable characters (see page 68) will be cleared as a result of correcting an expression in the program.

Deleting or Clearing Program Contents

- To delete a specific program line (an algebraic expression) from a program, call the title of the program you wish to delete on the display using the TITLE key, locate the line to be deleted, using the ↓ key in the AER mode, and then press the 2ndF and CA keys. The line has now been deleted from memory.

- To delete a specific program from memory, call the title of the program you wish to delete on the display by the title search operation in the AER mode, and press the 2ndF and CA keys. The following message will appear on the display.

```
○○: CLEAR  ?  →ENT
```

Then press the ENT key and the program (title name, main routine, and subroutines) will be deleted from memory. Memory contents will be retained by pressing the ON/C key.

- To clear all the programs stored in memory, push the Reset switch at the rear of the calculator in the AER mode, and the following message will appear on the display.

```
ALL  CLEAR  ?  →ENT
```

Then press the [ENT] key and all the programs stored in the AER mode will be cleared from memory. Memory contents will not be cleared when any key other than [ENT] is pressed.

CAUTION:

1. In the AER mode, do not use the [2ndF] [↑] key sequence while the title name is in the display.
2. In the AER mode, do not use the [2ndF] [↑] key sequence while writing a main routine or subroutine. If you press the [2ndF] [↑] keys during the process described in 1 and 2 above, insignificant data may appear in the display. In this case, press the [TITLE] key to return the display to the original state. Key operation other than [TITLE] may result in the destruction of memory contents.

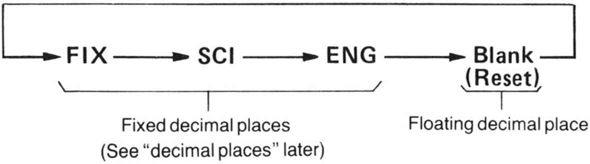
CHAPTER 4

DISPLAY SYSTEMS & DECIMAL PLACES

Display Systems

The EL-5150 has four different display systems which can be selected with the FSE (display mode control) key.

When you press the FSE key in the COMP mode, the display mode indicator "FIX", "SCI", or "ENG" or a blank (none of these) will appear at the upper part of the display. The FSE key is operative only after the result of a calculation has been displayed or when calculator is cleared with ON/C key.



The designated decimal point system and decimal places will be retained even when the calculator is turned off.

(1) FIX (FIXed decimal point system)

- Each calculation result is displayed after being rounded to the number of decimal places selected with the TAB key.
- When a calculation result is to be used for further calculations or formulas, the contents displayed will be used.

When the absolute value of a calculation result is less than 1, the result may be displayed in the exponential form (scientific notation) accoridng to the number of decimal place selected with the TAB key.

Example 1:
If the absolute value of a calculation result is 1 or more

ON/C FSE (To display FIX indicator)

TAB 3 (To fix the number of decimal places to 3)

5 ÷ 3 =

```
                    FIX
                                  1.667
```

×

```
                    FIX
1.667×_
```

Example 2:
If the absolute value of a calculation result is less than 1

ON/C 5 ÷ 9 =

```
                    FIX
                                  0.556
```

×

```
                    FIX
5.556E-01×_
```

(2) SCI (SCIentific notation)

- Calculation result is displayed with scientific notation ($A \times 10^B$).
Since the mantissa part of the calculation result is displayed in accordance with the decimal place designation (TAB), the number of significant digits can be easily designated. The next digit after the specified number of decimal places is automatically rounded off.

- When a calculation result is to be used for further calculations or formulas, the contents displayed will be used.

Example:

[ON/C] [FSE]   (To display SCI indicator)

[TAB] 2   (To fix the number of decimal places to 2)

.3 [÷] 7 [=]

```
                         SCI
                                   4. 29E-02
```

[+]

```
                         SCI
4. 29E-02+_
```

The above display means that the number of significant digits has been fixed to 3.

(3) ENG (ENGineering notation)

- Each calculation result is displayed on the basis of scientific notation ($A \times 10^{B}$). At this time its mantissa is displayed according to the decimal place designation (TAB) and the exponent is automatically set to a multiple of 3 (··· -6, -3, 0, 3, 6,···) for display. Therefore, any display can be easily read in units of K (kilo- 10^{3}) or m (milli- 10^{-3}), etc. that is commonly used in the engineering field.

- When a calculation result is to be used for further calculations or formulas, the contents displayed will be used.

(The next digit after the specified number of decimal places is automatically rounded off.)

Example:

[ON/C] [FSE]   (To display ENG indicator)

[TAB] 2   (To fix the number of decimal places to 2)

.3 [÷] 7 [=]

```
                         ENG
                                  42. 86E-03
```

×

```
                                ENG
42.86E-03×_
```

(4) Blank (i.e., when none of FIX, SCI, and ENG is displayed)

- Each calculation result is displayed in the floating decimal point system.
Calculation result x is displayed on the basis of scientific notation if it is outside the range of $0.000000001 \leq |x| \leq 9999999999$ or not zero.

- When a calculation result is to be used for further calculations or formulas, the calculator will secure as many significant digits as possible (10 digits max.) for the next formula.

Decimal Places

The [TAB] key is used to specify the number of decimal positions in a calculation result when the FIX, SCI, or ENG mode is set. The number of decimal places is specified by the numeral key ([0] - [9]) following the [TAB] key. Carry over will be automatically rounded.
Use the [TAB] key when the calculation result is displayed or when the calculator is cleared with the [ON/C] key.

Example:
If FIX mode is designated

[ON/C] [FSE] (To display FIX indicator)

[TAB] 9 (To fix the number of decimal places to 9)

5 [÷] 9 [=]

```
                    FIX
                   0. 5 5 5 5 5 5 5 5 6
```

[TAB] 8 (To fix the number of decimal places to 8)

```
                    FIX
                      0. 5 5 5 5 5 5 5 6
```

[TAB] 7 (To fix the number of decimal places to 7)

```
                    FIX
                        0. 5 5 5 5 5 5 6
```

[TAB] 0

```
                    FIX
                                    1.
```

Note:

1. If a number cannot be displayed in the number of decimal places specified by $\boxed{\text{TAB}}$, the number may be displayed in less than the number of decimal places specified by $\boxed{\text{TAB}}$.
2. The designated number of decimal places is retained even when the display system is changed or when the power is turned off.

Indicators

← : Indicates that the information (a portion of an expression or formula) that has already been displayed exists at the left of the information (a portion of the expression or formula) now on the display.

→ : Indicates that the information yet to be displayed continues to the right of the information now on the display. Also indicates that the calculator is performing a calculation.

2ndF : Indicates that the second function of another key has been specified.

HYP : Indicates that the hyperbolic function has been specified.

DEG : Indicates that "degrees" must be used as the angle of unit for the calculation.

RAD : Indicates that "radians" must be used as the angle of unit for the calculation.

GRAD : Indicates that "grads" must be used as the angle of unit for the calculation.

FIX : Indicates that the result of a calculation is to be displayed in the fixed decimal point system.

SCI : Indicates that the result of a calculation is to be displayed in the scientific notation system.

ENG : Indicates that the result of a calculation is to be displayed in the engineering notation system.

BIN : Indicates that the calculator is in the BIN (binary number system) mode or that the displayed number is a binary number.

OCT : Indicates that the calculator is in the OCT (octal number system) mode or that the displayed number is an octal number.

HEX : Indicates that the calculator is in the HEX (hexadecimal number system) mode or that the displayed number is a hexadecimal number.

STAT : Indicates that the calculator is in the STAT (statistical calculation) mode.

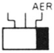
VAR : Indicates that the calculator is in the VAR (variable character input) mode.

APPENDIXES

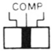
Appendix A
Operating Controls

Unless otherwise specified, the keys listed below can be used in either the COMP or AER mode.

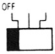
Mode Selector (Slide Switch)



AER: Algebraic Expression Reserve Mode
This mode is used to program algebraic expressions into the calculator's memory. In this mode, no calculation can be performed.



COMP: Compute mode
This mode permits the calculator to perform all calculations including four basic arithmeric operations, scientific calculations, statistical calculations, and calculations that use algebraic expressions programmed in the AER mode.



OFF: Setting the switch in this position turns off the power supply of the calculator. Sliding the switch from the OFF position to the COMP or AER turns on the power supply of the calculator.

2ndF : 2nd Function Key
Used to designate the second function of another key. The second function is printed in brown above the key top.
NOTE: If this key is pressed by mistake, press the key again to cancel the second function designation.

ON/C : ON/Clear Key

When the Auto Power-Off feature is active, pressing this key causes the calculator to turn on. This key is also used to release the calculator from an error condition.

COMP mode:

Used to clear numeric data or calculation commands from the display. The memory contents or programs will remain unchanged even after the clear operation. Pressing this key during a program execution breaks the execution.

AER mode:

Used to move the cursor to the beginning of the current line. If this key is pressed while a program title (with no cursor) is in the display, the title will be replaced with a message “00 :TITLE?”.

2ndF CA : Clear All Key

COMP mode:

Used to clear numeric data or calculation commands. The memory contents or programs will remain unchanged even after the clear operation. Also used to clear the result of a statistical calculation or statistical data entered in the STAT mode. (The contents of memories A ~ T will remain unchanged.)

AER mode:

If these keys are pressed while program contents are in the display, the program line now in the display will be cleared. If they are pressed while a program title is in the display, the title will be replaced with a message “00: CLEAR? → ENT”. Pressing the ENT key will delete the program of that title.

FSE : Display Mode Designation Key
COMP mode:
Used to select the display mode from FIX, SCI, and ENG.

2ndF DRG : Degrees/Radians/Grads Selection Key
Used to designate the unit of angle (DEG, RAD, or GRAD) for calculation of trigonometric and inverse trigonometric functions and for conversion of coordinates. Each depression of these keys causes the unit of angle to be changed from one unit to another.
Example: DEG → GRAD: Press the 2ndF DRG keys twice.

"DEG" - Entries and answers are in decimal degrees.
"RAD" - Entries and answers are in radians.
"GRAD" - Entries and answers are in grads.

$(100g = 90° = \frac{\pi}{2}\ (RAD))$

COMP : Compute Key
COMP mode:
Used to execute a stored program (algebraic expression).

PB : Playback Key
COMP mode:
Pressing this key allows you to check or correct all of the inputs or to display the last executed expression for re-execution. The input or expression called is displayed in 24-step segments.

AER mode:
Used to display the contents of the program line in 24-step segments.

[DEL] : Delete Key
Used to delete the character (number or letter) at the cursor position. (The cursor does not move.)

[2ndF] [INS] : Insert key
Provides a blank space necessary for insertion of a character (number or letter) into the cursor position. Pressing the [2ndF] and [INS] keys in this sequence shifts the contents of the display to the right. In the blank space, the insert mark "⊏⊐" appears.

[◄] : Cursor Step-Down Key
Used to move the cursor left by one step. While this key is being pressed and held, the cursor moves left in quick succession.

[►] : Cursor Step-Up Key
Used to move the cursor right by one step. While this key is being pressed and held, the cursor moves right in quick succession.

[Exp] : Exponent Key
Used to enter the exponent part of a number.
Example: 1.234×10^{15}
Key in: 1.234 [Exp] 15

NOTE:

The number of digits for the exponent part is 2 digits. A number with a decimal fraction may be entered, but the calculator ignores the decimal point in the calculation process. If more than two digits are entered, only the last two digits are effective as the exponent.

Example: COMP mode

Key in: 2 [Exp] 1234 [=] → "2. E 34" is displayed.

[TAB] : Tabulation Key

COMP mode:

Used to fix the number of decimal positions in a calculation result. The number of digits (0 ~ 9) must be entered following this key.

[2ndF] [ANS] : Recall Answer Memory Key

Used to recall the data stored in the answer memory.

[2ndF] [M.CK] : Memory Check Key

The remaining capacity of the memory is indicated in bytes on the display while these keys are being pressed and held.

[2ndF] [MDF] : Modify Key

COMP mode:

Used to match the internal calculation result with the calculation result in the display.

[+] : Plus Key

Pressed for addition.

[−] : Minus Key

Pressed for subtraction.

$\boxed{\times}$: Multiplication Key
Pressed for multiplication.

$\boxed{\div}$: Division Key
Pressed for division.

$\boxed{=}$: Equals Key
Used to obtain the result of a calculation.

$\boxed{0} \sim \boxed{9}$: Numeral Keys
Used to enter numeric data.
Example: 1 2 3 4 → $\boxed{1}\ \boxed{2}\ \boxed{3}\ \boxed{4}$

NOTE:
These keys are also used to enter numbers 0 ~ 9 reduced in size as variables in the VAR mode.

$\boxed{(}$: Open Parenthesis Key
Used to enter an open parenthesis.

$\boxed{)}$: Closed Parenthesis Key
Used to enter a closed parenthesis.

$\boxed{(-)}$: Change Sign Key
Used to enter a negative number.
Example: −2.4 → $\boxed{(-)}\ \boxed{2}\ \boxed{\cdot}\ \boxed{4}$

$\boxed{\cdot}$: Decimal Point Key
Used to place the decimal point in the number entered.
Example: 12.3 → $\boxed{1}\ \boxed{2}\ \boxed{\cdot}\ \boxed{3}$

$\boxed{\text{STO}}$: Store Key

Used to store a number in each of the 26 memories $\boxed{\text{A}}$ ~ $\boxed{\text{Z}}$ by pressing this key followed by one of the $\boxed{\text{A}}$ - $\boxed{\text{Z}}$ keys. When these keys (for example, $\boxed{\text{STO}}$ $\boxed{\text{A}}$) are pressed after a number (or a calculation result), the number is stored in memory A by clearing the contents previously stored in the memory.

$\boxed{\text{RCL}}$: Recall Key

Used to recall the contents of the designated memory. To recall each of the 26 memories A ~ Z, depress one of the $\boxed{\text{A}}$ - $\boxed{\text{Z}}$ keys following the $\boxed{\text{RCL}}$ key. (Example: $\boxed{\text{RCL}}$ $\boxed{\text{B}}$)

$\boxed{\text{A}}$ ~ $\boxed{\text{Z}}$: Memory Designation Keys

AER mode, COMP mode:

When one of the $\boxed{\text{A}}$ - $\boxed{\text{Z}}$ keys is pressed following the $\boxed{\text{STO}}$ or $\boxed{\text{RCL}}$ key, the corresponding store memory is designated.

VAR mode:

Used to enter lowercase letters (a to z) as variables.

$\boxed{\text{RM}}$: Recall Memory Key

Used to recall and display the contents of the independently accessible memory.

→M : Memory In Key
Used to store a calculation result in the independently accessible memory. When this key is pressed, the previous contents of the independently accessible memory is cleared and replaced with the calculation result. To clear the independent accessible memory, depress the ON/C key followed by the →M key. (In this case, 0 (zero) is stored in the memory.)

M+ :Memory Plus Key
Used to add a calculation result to the contents of the independently accessible memory.

2ndF M+ : Memory Minus Key
Used to subtract a calculation result from the contents of the independently accessible memory.

→DEG : D.MS → Decimal Degrees Conversion Key
Used to convert an angle in the sexagenary notation system (degrees, minutes, seconds) into decimal equivalent (in degrees).

2ndF →D.MS : Decimal Degrees → D.MS Conversion Key
Used to convert an angle in the decimal notation system (in degrees) into sexagenary equivalent (in degrees, minutes, seconds).

2ndF FRAC : Fraction Key
Used to determine and display the fraction part of a number.

2ndF INT	: Integer Key Used to determine and display the integer part of a number.
2ndF ABS	: Absolute Value Key Used to determine and display the absolute value of a number.
π	: Pi Key Used to enter the constant π (π = 3.141592654).
Y^x	: Power Key Used to raise a number to a power.
2ndF $\sqrt[x]{\ }$	: Power Root Key Used to obtain the power root of a number.
x^2	: Square Key Used for squaring.
$\sqrt{\ }$	: Square Root Key Used for square root calculations.
2ndF $\sqrt[3]{\ }$	: Cubic Root Key Used for cubic root calculations.
2ndF 10^x	: Common Antilogarithm Key Used to calculate the antilogarithm with base 10.
LN	: Natural Logarithm Key Used to obtain the logarithm with base e (e ≒ 2.718281828).
2ndF e^x	*: Natural Antilogarithm Key* Used to calculate the antilogarithm with base e of the displayed number.

LOG	: Common Logarithm Key Used to obtain the logarithm with base 10.
2ndF x^{-1}	: Reciprocal Key Used for reciprocal calculations.
HYP	: Hyperbolic Function Key Used with the respective trigonometric function keys to calculate hyperbolic functions (SINH, COSH, TANH).
2ndF ARCHYP	: Inverse Hyperbolic Function Key Used with the respective trigonometric function keys to calculate inverse hyperbolic functions (SINH^{-1}, COSH^{-1}, TANH^{-1}).
SIN COS TAN	: Trigonometric Function Keys Used to calculate the respective trigonometric functions.
2ndF SIN^{-1} 2ndF COS^{-1} 2ndF TAN^{-1}	: Inverse Trigonometric Function Keys Used to calculate the respective inverse trigonometric functions.
→POL	: Rectangular → Polar Coordinates Conversion Key Used to convert rectangular coordinates into polar coordinates.
2ndF →REC	: Polar → Rectangular Coordinates Conversion Key Used to convert polar coordinates into rectangular coordinates.
2ndF $n!$	: Factorial Key Used to calculate the factorial n! = n (n-1) (n-2) ..... 2·1.

nCr : Combinations Key
Used to determine the number of possible combinations when selecting a specific number of items (r) from any number of different items (n).

2ndF nPr : Permutations Key
Used to determine the number of possible permutations when arranging a specific number of items (r) selected from any number of different items (n).

2ndF →BIN : Binary Number Mode Key
COMP mode:
Used to set the binary number system mode. Also used to convert the number displayed into a binary number.

2ndF →OCT : Octal Number Mode Key
COMP mode: Used to set the octal number system mode. Also used to convert the number displayed into an octal number.

2ndF →HEX : Hexadecimal Number Mode key
COMP mode:
Used to set the hexadecimal number system mode. Also used to convert the number displayed into a hexadecimal number.

2ndF →DEC : Decimal Number Mode Key
COMP mode:
Used to set the decimal number system mode (normal mode). Also used to convert the number displayed into a decimal number.

NEG : Negative Key
BIN, OCT, or HEX mode:
Used to obtain the negative counterpart of a number.

Hexadecimal Number Key
HEX mode:

A : Used to enter hexadecimal number "A".

B : Used to enter hexadecimal number "B".

C : Used to enter hexadecimal number "C".

D : Used to enter hexadecimal number "D".

E : Used to enter hexadecimal number "E".

F : Used to enter hexadecimal number "F".

Logical Operator Keys
BIN, OCT, HEX mode:

NOT NOT Key
: Used to enter logical operator "NOT".

AND : AND Key
Used to enter logical operator "AND".

OR : OR Key
Used to enter logical operator "OR".

XOR : Exclusive OR Key
Used to enter logical operator "XOR" (exclusive OR).

XNOR : Exclusive NOR Key
Used to enter logical operator "XNOR" (exclusive NOR).

2ndF STAT : Statistical Calculation Mode Key
COMP mode:
Used to set or reset the STAT (statistical calculation) mode. When the calculator is set in this mode by these keys, the " STAT " indicator appears, and at the same time the numeric values and calculation commands, except for memory contents are cleared.

(x,y) : Two-Variable Data Designation Key
STAT mode:
Used to distinguish between data *x* and data y in two-variable statistical calculations.

DATA : Enter Data Key
STAT mode:
Used to enter data in single- or two-variable statistical calculations.

CD : Correct Data Key
STAT mode:
Used to correct an error in statistical data entry.

Statistical Calculation Keys
STAT Mode:

2ndF n : Used to obtain the number of samples (data) entered in single- or two-variable statistical calculations.

2ndF Σx : Used to obtain the sum of data *x* entered in single- or two-variable statistical calculations.

2ndF Σy : Used to obtain the sum of data y entered in two-variable statistical calculations.

2ndF Σxy : Used to obtain the sum of the products of data *x* and y in two-variable statistical calculations.

2ndF Σx^2 : Used to obtain the sum of the squares of each data x entered in single- or two-variable statistical calculations.

2ndF Σy^2 : Used to obtain the sum of the squares of each data y entered in two-variable statistical calculations.

2ndF $\bar{x}$: Used to obtain the mean value of data *x* entered in single- or two-variable statistical calculations.

2ndF $\bar{y}$: Used to obtain the mean value of data y entered in two-variable statistical calculations.

2ndF σx : Used to obtain the standard deviation (σx) of the population of data *x* entered in single- or two-variable statistical calculations.

2ndF σy : Used to obtain the standard deviation (σy) of the population data y entered in two-variable statistical calculations.

2ndF Sx : Used to obtain the standard deviation (Sx) of the sample of data *x* entered in single- or two-variable statistical calculations.

2ndF Sy : Used to obtain the standard deviation (Sy) of the sample of data y entered in two-variable statistical calculations.

2ndF (x')	: Used to obtain the estimated value of x. (In linear regression equation y = a + bx, the value of x is estimated from that of y.)
2ndF (y')	: Used to obtain the estimated value of y. (In linear regression equation y = a + bx, the value of y is estimated from that of x.)
2ndF (a)	: Used to obtain the constant a of linear regression equation y = a + bx.
2ndF (b)	: Used to obtain the coefficient b of linear regression equation y = a + bx.
2ndF (r)	: Used to obtain the correlation coefficient between two variables (or data) x and y.

Program Title Search Keys

TITLE	: Used to search program titles in the ascending order of title numbers. While this key is being pressed and held, program titles are searched in quick succession.
2ndF TITLE	: Used to search program titles in the descending order of title numbers.

Program Scroll Keys
AER mode:

↓	: Used to scroll a stored program one line after another in the forward direction. While this key is being pressed and held, program lines are scrolled in quick succession.
2ndF ↑	: Used to scroll a stored programs one line after another in the reverse direction.

[ENT]	: Enter Key AER mode: Used to store a program (algebraic expression) in memory.
[2ndF] [◣]	: End Command Key AER mode: Used to terminate program execution. (These keys are used as the End command of an algebraic expression.)
	Looping Keys AER mode:
[2ndF] [↳]	: Used to specify the destination of a jump caused by the " ↰ " command.
[2ndF] [↰]	: Used to cause program execution to jump to the point where the " ↳ " command is located.
	Compare Keys AER mode:
[2ndF] [>]	: Used to determine if the magnitude of the left side of an expression is greater than that of its right side.
[2ndF] [>=]	: Used to determine if the magnitude of the left side of an expression is equal to or greater than that of its right side.
[2ndF] [≠]	: Used to determine if the left side of an expression is not equal to its right side.
[SUB :]	: Subroutine Key AER mode: Used for writing a subroutine.

Conditional Jump Destination keys
AER mode:

2ndF Y→[ ] :Used to specify the destination of a jump if the result of conditional expression judgment is "Yes".

2ndF N→[ ] : Used to specify the destination of a jump required if the result of conditional expression judgmends is "No".

␣ : Space Key
AER mode:
Used to enter spaces (␣) which are used to separate two or more expressions or formulas in a program to be stored.

, : Comma Key
AER mode:
Used to enter commas (,) which are used to separate two or more expressions or formulas in a program to be stored.

f( )= : Variable Designation Key
AER mode:
Used to designate store memories (A~ Z) as the variables of an expression or formula. For example, when you press f( )= A B f( )= , expression f(AB) = is entered and store memories A and B are designated as variables.

2ndF VAR : Variable Character Input Mode Key
AER Mode:
Used to set the VAR mode when you wish to enter any of characters for variables for programming. The VAR indicator appears in the display while the calculator is in the VAR mode.

$\boxed{\alpha}$: Alpha key

VAR mode:

Used to enter Greek letter "α" as a variable.

$\boxed{\beta}$: Beta Key

VAR mode:

Used to enter Greek letter "β" as a variable.

$\boxed{\gamma}$: Gamma Key

VAR mode:

Used to enter Greek letter "γ" as a variable.

$\boxed{\theta}$: Theta Key

VAR mode:

Used to enter Greek letter "θ" as a variable.

Appendix B
Accuracy of Calculation

- Entries, and four basic arithmetic operation, 1st, 2nd operands, and calculation results:
  $\pm 1 \times 10^{-99}$ to $\pm 9.999999999 \times 10^{99}$ and 0

  NOTE:
  When the absolute value of a numeric entry or the result of a calculation is less than 1×10^{-99}, this calculator regards the value as 0 (zero) for calculation or display.

- Scientific and special functions:

Functions	Dynamic range
SIN x COS x TAN x	DEG: $\lvert x \rvert < 1 \times 10^{10}$ RAD: $\lvert x \rvert < \frac{\pi}{180} \times 10^{10}$ GRAD: $\lvert x \rvert < \frac{10}{9} \times 10^{10}$ With TAN X, however, an error occurs in the following cases: DEG: $\lvert x \rvert = 90(2n-1)$ RAD: $\lvert x \rvert = \frac{\pi}{2}(2n-1)$ GRAD: $\lvert x \rvert = 100(2n-1)$ (n= integer)
SIN^{-1} x COS^{-1} x	$-1 \leqq x \leqq 1$
TAN^{-1} x	$\lvert x \rvert < 1 \times 10^{100}$
LN x LOG x	$1 \times 10^{-99} \leqq x < 1 \times 10^{100}$
e^{x}	$-1 \times 10^{100} < x < 230.2585093$
10^{x}	$-1 \times 10^{100} < x < 100$

Functions	Dynamic range
y^x	● $y>0$ $-1\times10^{100} < x \text{ LOG}y < 100$ ● $y=0$ $0<x<10^{100}$ ● $y<0$ $-1\times10^{100}<x \text{ LOG } \mid y \mid <100$ where x : integer or $\frac{1}{x}$: odd number$(x\neq0)$
$\sqrt[x]{y}$	● $y>0$ $-1\times10^{100}<\frac{1}{x}\text{LOG } y<100 \quad (x\neq0)$ ● $y=0$ $0<x<10^{100}$ ● $y<0$ $-1\times10^{100}<\frac{1}{x}\text{LOG } \mid y \mid <100$ where x : odd number or $\frac{1}{x}$: integer$(x\neq0)$
$\sqrt[3]{x}$	$\mid x \mid <1\times10^{100}$
SINH x COSH x TANH x	$-227.9559243<x<230.2585093$
SINH^{-1} x	$\mid x \mid <1\times10^{50}$
COSH^{-1} x	$1\leqq x<1\times10^{50}$
TANH^{-1} x	$\mid x \mid <1$
$\sqrt{x}$	$0\leqq x<1\times10^{100}$
x^2	$\mid x \mid <1\times10^{50}$
x^{-1}	$\mid x \mid <1\times10^{100} \quad (x\neq0)$
n!	$0\leqq n\leqq69$ (n : integer)
xCy xPy	$0\leqq y\leqq x\leqq69$ (x,y : integer)
→POL	$\mid x \mid <1\times10^{50}, \quad \mid y \mid <1\times10^{50}$ $x^2+y^2<1\times10^{100}$ $\mid \frac{y}{x} \mid <1\times10^{100}$
→REC	$0\leqq\gamma < 1\times10^{100}$ Same range as trigonometric functions apply to the angle

Functions	Dynamic range
→DEG →D.MS	$\lvert x \rvert < 1 \times 10^{100}$
Conversions	Converted result :
→DEC	DEC : $\lvert x \rvert$ ≦9999999999
→BIN	BIN : ●$\underbrace{1000000000000000}_{\text{16 digits}}$ ≦x≦1111111111111111 ●0≦x≦0111111111111111
→OCT	OCT :●4000000000≦x≦7777777777 ●0≦x≦3777777777
→HEX	HEX :●FDABF41C01≦x≦FFFFFFFFFF ●0≦x≦2540BE3FF
Binary/octal/ hexadecimal number calculations NOT	BIN : ●1000000000000000 ≦x≦1111111111111111 ●0≦x≦0111111111111111 OCT :●4000000000 ≦x≦7777777777 ●0≦x≦3777777777 HEX : ●FDABF41C01 ≦x≦FFFFFFFFFF ●0≦x≦2540BE3FE
NEG	BIN : ●1000000000000001 ≦x≦1111111111111111 ●0≦x≦0111111111111111 OCT :●4000000001 ≦x≦7777777777 ●0≦x≦3777777777 HEX : ●FDABF41C01 ≦x≦FFFFFFFFFF ●0≦x≦2540BE3FF
Other binary/octal hexadecimal number calculations	The ranges for entries and calculation results in each mode are the same as the above conversions

Functions		Dynamic range
Statistical calculation	DATA CD	$\lvert x \rvert < 1 \times 10^{50}$ $\lvert y \rvert < 1 \times 10^{50}$ $\lvert \Sigma x \rvert < 1 \times 10^{100}$ $\Sigma x^2 < 1 \times 10^{100}$ $\lvert \Sigma y \rvert < 1 \times 10^{100}$ $\Sigma y^2 < 1 \times 10^{100}$ $\lvert \Sigma xy \rvert < 1 \times 10^{100}$ $\lvert n \rvert < 1 \times 10^{100}$
	$\bar{x}$	$n \neq 0$
	Sx	$n \neq 0,1$ $\lvert \Sigma x \rvert < 1 \times 10^{50}$ $0 \leqq \frac{\Sigma x^2 - (\Sigma x)^2/n}{n-1} < 1 \times 10^{100}$
	σx	$n \neq 0$ $\lvert \Sigma x \rvert < 1 \times 10^{50}$ $0 \leqq \frac{\Sigma x^2 - (\Sigma x)^2/n}{n} < 1 \times 10^{100}$
	$\bar{y}$ Sy σy	Same as $\bar{x}$, Sx, σx
	r	$n \neq 0$ $\lvert \Sigma x \rvert < 1 \times 10^{50}$ $\lvert \Sigma y \rvert < 1 \times 10^{50}$ $0 < (\Sigma x^2 - \frac{(\Sigma x)^2}{n})(\Sigma y^2 - \frac{(\Sigma y)^2}{n}) < 1 \times 10^{100}$ $\lvert \Sigma xy - \frac{\Sigma x \Sigma y}{n} \rvert < 1 \times 10^{100}$ $\left\lvert \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{n}}{\sqrt{(\Sigma x^2 - \frac{(\Sigma x)^2}{n})(\Sigma y^2 - \frac{(\Sigma y)^2}{n})}} \right\rvert < 1 \times 10^{100}$
	b	$n \neq 0$ $\lvert \Sigma x \rvert < 1 \times 10^{50}$ $\lvert (\Sigma x)(\Sigma y) \rvert < 1 \times 10^{100}$ $0 < \lvert \Sigma x^2 - \frac{(\Sigma x)^2}{n} \rvert < 1 \times 10^{100}$ $\lvert \Sigma xy - \frac{\Sigma x \Sigma y}{n} \rvert < 1 \times 10^{100}$ $\left\lvert \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{n}}{\Sigma x^2 - \frac{(\Sigma x)^2}{n}} \right\rvert < 1 \times 10^{100}$

Functions		Dynamic range
	a	Same as b, except the following: $\mid b\bar{x} \mid < 1 \times 10^{100}$ $\mid \bar{y} - b\bar{x} \mid < 1 \times 10^{100}$
	y′	$\mid bx \mid < 1 \times 10^{100}$ $\mid a + bx \mid < 1 \times 10^{100}$
	x′	$\mid y - a \mid < 1 \times 10^{100}$ $\left\| \frac{y-a}{b} \right\| < 1 \times 10^{100}$

NOTE:

In the above calculation range, the calculation results or intermediate results are treated or displayed as 0 (zero) when their absolute values are less than 1×10^{-99}.

- As a rule, the error of functional calculations is less than ±1 at the lowest digit of a displayed numerical value (at the lowest digit of mantissa in the case of scientific notation system) within the above calculation range. In the calculation of SINH x and TANH x, x is a singular point when it is 0 (zero). Near this point the error is accumulated, reducing the accuracy.

Appendix C
How to Check Remaining Bytes

How To Check Remaining Bytes

To confirm the number of bytes (for example, 1427 bytes) remaining in memory, press the 2ndF and M.CK keys. Keep pressing the M.CK key following 2ndF, and the display will show the number of bytes left in the memory as follows.

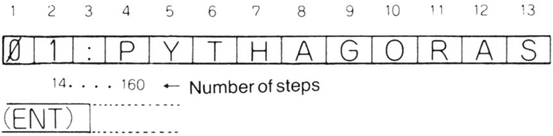
```
1427 BYTES LEFT
```

When you store a number of programs (algebraic expressions) in memory, write a program into memory while confirming the remaining bytes from time to time through this operation. Bytes are the number of bits that a computer or programmable calculator processes as a unit. With the EL-5150, one byte corresponds to one program step.

How To Count Number of Program Steps

A program titled "PYTHAGORAS" and stored in memory in the programming example on page 69 is used here as an example of counting the number of steps.

- Title



Because a title is stored in memory as shown in the above example, a memory space of 14 steps is required in this case. The total number of steps for a title consists of the number of title characters plus 4 steps.

- Main routine and subroutine

1	2	3	4	5	6	7	8	9	10	11	12	13
M:	f(	A	B	)=	√	(	A	x^2	+	B	x^2	)

14 ········· 160 ← Number of steps

(ENT)

The total number of steps for entry of a main routine or subroutine consists of the number of steps entered plus 2 steps.

NOTE:

1. ENT and SUB: keys are not included in the 160 steps permitted for a program entry, but these key entries require one byte of memory.
2. If variable characters are used for an algebraic expression, the calculator counts the total number of steps by adding the number of characters used as variables and 11 steps per variable to the number of steps entered.
3. If message "ERROR 4" appears in the display while writing an algebraic expression in memory, press the ON/C key to clear the error condition. Press the 2ndF and M.CK keys to check the remaining bytes and then either delete the excessive portion of the program contents previously stored in memory or enter the contents of the expression being programmed so as not to exeed the remaining bytes.

Appendix D
Error Conditions & Messages

Error Conditions

If you attempt to execute an operation exceeding the calculation range of the calculator or any illegal operation, the unit will detect such operation as an error condition and indicate the pertinent error code or message, prohibiting you from subsequent operations. To clear the error condition, press the ON/C key (or the PB key).

- If an error occurs, press the PB key and the location of the error will be indicated by a blinking cursor.

1 ÷ 0 + 5 =

```
ERROR  2
```

PB

```
1 ÷ 0 + 5 =
```

Error Messages

Code	Description of Error
ERROR 1 -	– Syntax error (e.g., 3 × + 2)
ERROR 2 -	– Operational error: ● Result of an operation or the value of a pending operation exceeds the calculation range of the calculator. (See APPENDIX B for the calculation range.) ● Division by zero was attempted. ● Numeric entry exceeds the input range of the function in a scientific calculation. ● Statistical data for single-variable operation coexists with that for two-variable operation in the STAT mode.

- Illegal operation was attempted (e.g.,$\sqrt{-1}$) or a scientific calculation was attempted in the BIN, OCT, or HEX mode.

ERROR 3 - – Nesting error:

- Data or function exceeds the capacity of 8-stage data buffers or 16-stage function buffers.
- More than 15 loops are used in the looping feature.
- Attempt was made to jump from one subroutine to another.
- Attempt was made to display the calculation result of an expression more than 1,000 times.

ERROR 4 - – Memory error/overflow:

- Program (or expression) exceeds the memory capacity.
- An error related to memory exists.

- If an error is found in a program (or expression) stored in the AER mode and executed with the $\boxed{\text{COMP}}$ key in the COMP mode, main("M:") or subroutine (e.g., " 1 ") indicator where the error has occurred will appear in the display, followed by the pertinent error code.

Example:

```
M: ERROR   1
```

↑ Indicates that the error exists in a main routine.

To review the erroneous program line, press the $\boxed{\text{PB}}$ key. The program line with a blinking cursor showing the location of the error will appear in the display when you keep pressing the $\boxed{\text{PB}}$ key.

Appendix E
Priority Levels In Calculation & Pending Operations

Priority Levels

The EL-5150 is provided with a function that judges the priority levels of individual calculations. Normally, the unit permits you to perform the key operation of a given algebraic formula as written. The following shows the priority levels of individual calculations.

(1) (–)

(2) π, recall of memory contents, recall of answer memory

(3) Single-term function preceded by a number
(Example: x^2, x^{-1}, n!, →DEG, →D.MS)

(4) Two-term function preceded and followed by a number
(Example: nCr, nPr, Y^x, $\sqrt[x]{\ }$, →POL, →REC)

(5) Multiplication where "×" command located just before a store memory or before a single-term function followed by a number has been omitted from entry.
(Example: 2π, 4A)

(6) Single-term function followed by a number
(Example: $\sqrt{\ }$, e^x, 10^x, $\sqrt[3]{\ }$, LN, LOG, SIN, COS, TAN, SIN^{-1}, COS^{-1}, TAN^{-1}, SINH, COSH, TANH, $SINH^{-1}$, $COSH^{-1}$, $TANH^{-1}$, ABS, INT, FRAC, NEG, NOT)

(7) ×, ÷

(8) +, –

(9) AND

(10) OR, XOR, XNOR

(11) =, M+, M– (2ndF M+), ⇒M, STO A ~ STO Z, →BIN, →OCT, →HEX, →DEC, ␣ (space), , (comma), DATA, CD, (x,y),x',y', >, >=, ≠ ,↳, ↰, –Y→[], –N→[], ◣, etc.

- Parenthesized calculations have precedence to any other calculations.

- Provided that functions shown in item (6) above are successively designated in an algebraic expression, calculations are performed from the right to the left.

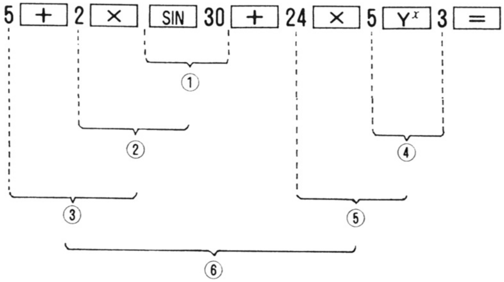
Ex. $e^x \mathrm{LN} \sqrt{\quad}\ 120 \rightarrow e^x \{\mathrm{LN}(\sqrt{\quad}\ 120)\}$

- The other functions are calculated from the left to the right.

Ex. $A\ {}^x\!\sqrt{\quad}\ BY^xCY^xD \rightarrow \{(A\ {}^x\!\sqrt{\quad}\ B)Y^xC\}Y^xD$

Order of calculations in a typical example:

Ex. $5 + 2 \times \mathrm{SIN}\,30 + 24 \times 5^3 =$



Pending Operations

When the calculator performs calculations according to the established priority levels or performs a parenthesized calculation before any other calculations, the unit must suspend or set aside the calculation commands and numbers (or values) that cannot be processed immediately. For this reason, the calculator is provided with a memory area for pending operations, consisting of a 16-stage function buffer and a 8-stage data buffer. In other words, a maximum of 16 calculation commands and a maximum of 8 numbers can be stored in the memory area. Note that an error condition occurs if this memory capacity is exceeded by these pending operations.

Example 1

Calculation with 8 pending numbers

$$\underset{①}{1} + \underset{②}{2} \times (\underset{③}{3} - \underset{④}{4} \div (\underset{⑤}{7} \div \underset{⑥}{5} \sqrt[x]{} (\underset{⑦}{7} \times \underset{⑧}{6} Y^x 3 =$$

$$\underset{①}{14 - 5} + \underset{②}{4} \times \mathrm{SIN}\underset{③④}{2A} Y^x (\underset{⑤}{2} + \underset{⑥}{3} \div \mathrm{LOG}\underset{⑦⑧}{3B} \sqrt[x]{} 48 =$$

When the calculator reaches the next Add "+" command, it executes 14−5 and holds the calculation result of 9 in the data buffer.

Store memory such as A or B is regarded as a number and is temporarily held in the data buffer.

Example 2:

Calculation with 16 calculation commands including parentheses

$$\underset{①②}{((}\underset{③}{2+}\underset{④}{12 \div 4 \times} 3\underset{⑤}{Y^x}\underset{⑥\sim⑨}{((((}\underset{⑩}{3+2-}\underset{⑪}{4\sqrt{}}\ \underset{⑫}{\mathrm{LOG}}\underset{⑬}{\sqrt[3]{}}\ \underset{⑭}{4}\underset{⑮⑯}{A^2}$$

When the calculator reaches "×" Command, it executes division 12 ÷ 4, with the result of 3 ×.

When the calculator reaches the "−" command, it executes addition 3+2, with the result of 5−.

"×" command was omitted from entry ($4\times\sqrt{}$, $4\times A^2$) but the calculator assumes the presence of the "×" command when executing the multiplication.

Appendix F
Battery Replacement

The EL-5150 uses two lithium batteries as its main DC power supply. The calculator also uses another lithium battery for memory backup.

- When replacing either of the two types of batteries, be sure to set the Model Selector switch of the calculator to the OFF position.
- Do not replace the batteries for main DC power and memory backup at the same time, or the memory contents of the calculator may be lost.

When to Replace Batteries for Main DC Power Supply

The Contrast knob is located on the right side of the calculator as viewed from its front. Turn the knob counterclockwise for a higher contrast. If the indicators and numbers in the display (LCD) appear to be dim, it is the signs of the low battery voltage, meaning that the batteries are nearing the end of their life. Replace the batteries as quickly as possible. Note that use of the calculator with the exhausted batteries may result in loss of the memory contents.

How to Replace Batteries for Main DC Power Supply

(1) Slide the Mode Selector switch to the OFF position to turn off the power.

(2) Remove the two set screws with a phillips screwdriver from the rear of the calculator and detach the rear cover.

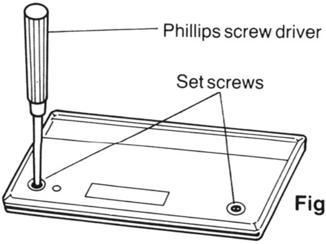


Fig. 1

(3) Slide the Battery ON/OFF switch to the OFF position.

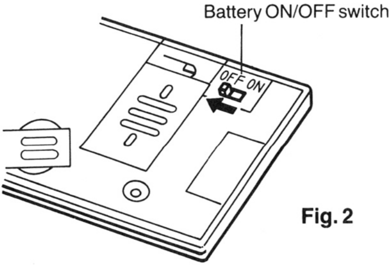


Fig. 2

(4) Push the stopper to slide the battery keep plate in the direction of the arrow and remove the keep plate.

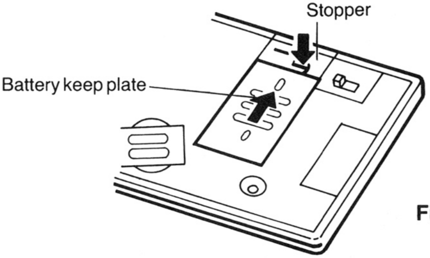


Fig. 3

(5) Remove the two old batteries from the battery compartment and replace them with two new ones (CR-2032 lithium batteries) with attention paid to the polarity as shown in Fig. 4. Before inserting the two new batteries, wipe them clean with a dry cloth. When replacing the main DC power supply, do not unload the memory backup battery.

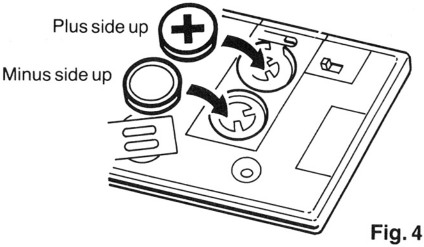


Fig. 4

(6) Put the battery keep plate back to its original position, push the Reset switch, and then slide the battery ON/OFF switch to the ON position.

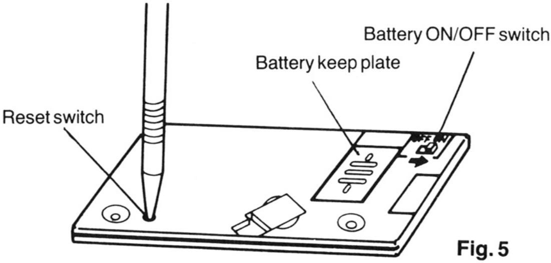


Fig. 5

(7) Hooks the four claws (or projections) of the rear cover into the corresponding slots at the side of the calculator and secure the rear cover to the unit with the two setscrews while gently holding down the rear cover.

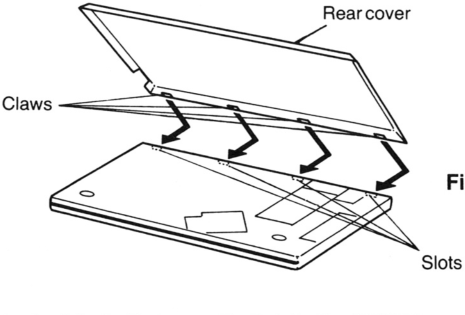
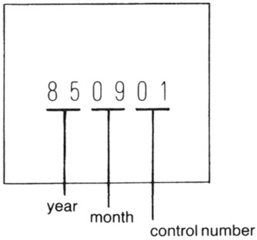


Fig. 6

(8) Slide the Mode Selector Switch to the COMP position and push the Reset switch again to confirm that "0." is appearing in the display. If not, unload the batteries and repeat the battery replacement procedure from the beginning.

Life of Memory Backup Battery

The memory backup battery will protect the calculator's memory contents for about 5 years at a room temperature of 20°C. The date (year and month) of battery loading is indicated on the label attached to the rear of the calculator at the time of its shipment. Refer to this date for determining the appropriate time of battery replacement.



NOTE:

The service life of the battery is governed by its operating environments and may be shortened from use at extremely high or low temperatures. In the worst case, this may result in loss of data or destruction of the memory contents.

How to Replace Memory Backup Battery

Before replacing the backup battery, make sure that the batteries for the main DC power supply have not become exhausted. If exhausted, replace the main batteries first and then the backup battery, or the memory contents of the calculator may be lost.

(1) Slide the Mode Selector switch to the OFF position.

(2) Remove the two setscrews from the rear of the calculator and detach the rear cover as shown in Fig. 1.

(3) Unscrew the battery keep plate with a phillips screwdriver and remove it.

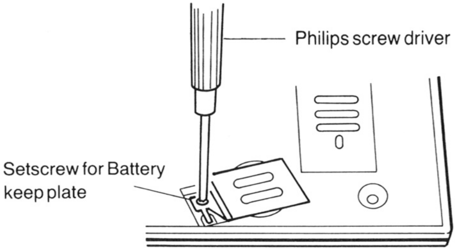


Fig. 7

(4) Remove the old battery and replace it with a new one (CR-2032 lithium battery) with attention paid to the polarity as shown in Fig. 8. Before inserting the new battery, wipe it clean with a dry cloth.

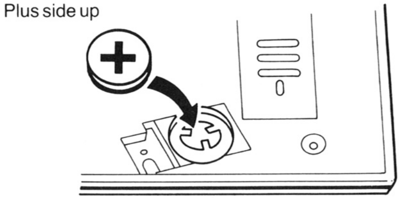


Fig. 8

(5) Secure the battery keep plate with the setscrew.

(6) Secure the rear cover to the unit as shown in Fig. 6.

Hints on Use of Batteries

1. When replacing the two main batteries, be sure to replace both batteries at the same time.
2. Avoid replacing the main batteries with one fresh and one used batteries combined.
3. Use the lithium batteries of the same type for replacement.
4. Insert the replacement batteries with attention paid to the polarity as indicated in the battery compartment (i.e., plus side up and minus side up).

5. Replace the memory backup battery every 5 years.

Cautions

- Keep the batteries out of reach of children.
- Dispose of old batteries safely. The batteries may explode if placed in a fire.
- The original batteries were installed upon shipment from the factory, so the battery life may be somewhat less than the normal 420 hours operating time.
- Remove the batteries when they become exhausted or if they are to be stored indefinitely. The batteries may leak and cause damage.

Date of Battery Replacement Label

A label is attached to the inside of the plastic cover to enter the date of battery replacement. Be sure to enter the initial date of replacement so that it may be used as a guide in determining the appropriate time of subsequent replacement.

Appendix G

Specifications

Model:	EL-5150
Number of internal calculation digits:	Mantissa: 12 digits; Exponent: 2 digits
Calculation system:	As per algebraic expression (with priority judging function)
Memory:	26 memories A-Z (one independent accessible memory or store memory and 25 store memories)
Display type:	Dot matrix liquid crystal display (24 digits, 5x7 dots)
Display capacity/mode:	Mantissa: 10 digits; Exponents: 2 digits Automatic changeover between the floating decimal point display system and any of the following display systems: Fixed decimal point system (FIX) Scientific notation (SCI) Engineering notation (ENG)
Calculations:	Four basic arithmetic operations, trigonometric and inverse trigonometric functions, hyperbolic and inverse hyperbolic functions, conversion of angles, reciprocals, square root and cubic root, square and power, logarithmic and exponential functions, Xth

root of Y ($\sqrt[x]{y}$), factorial, permutations, combinations, conversions of coordinates, memory calculations, statistical calculations, binary/octal/hexadecimal number calculations, logical operations, absolute value, integer/fraction part, modify, answer memory, etc.

Memory check function: Remaining bytes is displayed

AER functions: Variable designation, expression separation, end of command, conditional judgement, looping, subroutine, title search, etc.

General calculation capacity: 160 steps

Algebraic expression reserve capacity: 1,454 steps

Display control function: Cursor step-up, cursor step-down, insertion, deletion, and playback

Components: LSI, etc.

Power supply: 6V⎓(DC) main: Lithium battery (CR2032)×2
3V⎓(DC) backup: Lithium battery (CR2032)×1

Power consumption: 0.015W

Operating time: Approx. 420 hours continuous (at 20°C with 10-minute operation/hour, 50-minute display)

Memory backup:	Approx. 5 years
Operating temperature:	0° to 40°C (32° to 104°F)
Dimensions:	6–21/32″ (W)×2–13/16″ (D)×7/16″ (H)
Weight:	0.29 lb (including batteries)
Accessories:	Plastic cover, 3 built-in lithium batteries and Operation Manual

Appendix H
Scientific & Calculator Functions

Scientific Functions

Trigonometric	sin, cos, tan	3
	$\sin^{-1}$, $\cos^{-1}$, $\tan^{-1}$	3
Logarithmic	e^x, 10^x, ln, log	4
Power, Power Root	$\sqrt[x]{\quad}$, y^x	2
Algebraic	x^2, $\sqrt{\quad}$, $\sqrt[3]{\quad}$, x^{-1}	4
Angle Mode	DEG, RAD, GRAD	3
Angular Unit Conversion	→D.MS, →DEG	2
Coordinate Conversion	→REC, →POL	2
Hyperbolic	sinh, cosh, tanh	3
	$\sinh^{-1}$, $\cosh^{-1}$, $\tanh^{-1}$	3
Number System		
Conversion	→HEX, →OCT, →BIN, →DEC	12
Calculation (HEX, OCT, BIN)	HEX, OCT, BIN, NEG	4
Logical Operations	NOT, AND, OR, XOR, XNOR	5
Statistical		
Basic Statistics	n, Σx, Σx^2, $\bar{x}$, σx, Sx	6
	CD, multiple data points	2
	Σxy, Σy, Σy^2, $\bar{y}$, σy, Sy,	6
Regression	r, a, b	3
Prediction	x', y'	2
Modifying	MDF	1
Factorial	n!	1
Permutations, Combinations	nPr, nCr	2
Abs. Value, Integer, Fraction	ABS, INT, FRAC	3
Parentheses (Open/Close), Pending Operations	( )	3
Display	FIX, SCI, ENG, TAB	4
Data Entry	π, Exp	2
Total		85

Calculator Functions

Clear, Edit	C, CA, ◀, ▶, INS, DEL, PB	7
Arithmetic	+, −, ×, ÷	4
Memory	⇒M, RM, M+, 2ndF M+ (M−)	4
	A, B, C ... L, N ... Z	25
Negative Number Entry	(−)	1
Last Answer Recall	ANS	1
Total		42

Programming Functions

Variable Entry	f( )=, VAR	2
Formula Separation	, , ⌴, ◣	3
Conditional Expression Judging	>, >=, =	3
Branching	−Y→[], −N→[]	2
Looping	↳ , ↰	1
Addressing	(99 Addresses/Titles)	1
Title Search	TITLE, 2ndF TITLE	2
Program Scrolling	↓, ↑,	2
Subroutines	SUB:	1
Compute	COMP	1
Total		18

145	Functions
85	Scientific
42	Calculator
18	Programming

EL-5150
APPLICATION BOOK

Contents

Page

Introduction 1

Mathematics 3

Feet-inches Conversion 3

Triangle Solutions 4

Moving Averages 8

Quadratic Equation 9

Polynomials 11

Series 13

Matrices 16

Three-Variable Linear Equations 19

Random Number Generation 20

Statistics 22

Linear Regression 23

Non-Linear Regression 24

Curve Fitting 29

"t" Test 32

Chi-Square Test 34

Physics 37

Launching a Projectile 37

Orbiting 38

Moment of Inertia 45

Electronics 49

Parallel Resistance and Series Capacitance 49

Series Reactance and Impedance 50

Parallel Reactance and Impedance 53

Multiple Feedback Bandpass Filter 55

Chemistry 58

Ideal Gas Equation 58

Mechanics 61
Solar Energy 61
Pressure Loss 63
Uniformly Loaded Wood Beams 64
Trenching 71
Earthmoving 74

Business 77
Break-Even Analysis 77
Depreciation 80
Interest Calculations 86
Amortizations 88
Cash Flow Analysis 91
IRA Analysis 94
Present Worth of a Bond 96
Yiele to Maturity 97

Introduction

The EL-5150 Scientific Calculator is an extremely valuable tool for mathematical analyses. It features a complete display of the expression being evaluated, plus the ability to edit before or after calculation. Checking is quick and accurate, because almost all expressions are in conventional mathematical forms.

The versatility of the EL-5150 is illustrated in this book with examples drawn from a wide variety of disciplines. The unusual capabilities of the EL-5150 used throughout the book are:

1. Parentheses do not have to be opened if they occur at the beginning of an expression. Closing of parentheses at the end of an expression is also not required.

2. A large number of variables including 26 capital letters, 26 lower-case letters, 10 small digits (0 to 9), and 4 Greek letters. Combinations may be made of all these characters. Because of these capabilities, variables closely approximating those used in the actual disciplines are possible.

3. Conditionals and looping can be used with a minimum of programming.

4. The ability to store up to 99 equations and to quickly search for the program required by the use of the TITLE key.

5. The use of up to 10 subroutines within a program to either shorten the main program or to provide for different solutions to the same program.

6. Storing data in the STAT mode for use in the COMP mode.

The reader should work through all the keyboard solutions in the book even if the subject matter does not apply to the reader's particular interests. The techniques used in one field may also apply to other fields.

NOTICE

The material contained herein is supplied without representation or warranty of any kind. Sharp Electronics Corporation therefore assumes no responsibility and shall have no liability, consequential or otherwise, of any kind arising from the use of this material.

Mathematics

Feet-Inches Conversion

Adding or subtracting dimensions given as feet and inches can be difficult and confusing. In many applications it is necessary to convert dimensions given in feet and inches to decimal equivalents.

Program Notes:
All dimensions given in inches are converted to their decimal equivalents in feet. A variable can be added to a stored value in the next operation without repeating the stored value.

(1) Programming
MODE: AER

Display	Key in
TITLE ?	F R A C ENT
M:	f()= F I f()= 2ndF 1 ⌴ INT A, FRAC A×12 SUB:
1:	F + I ÷ 12 STO B + A STO A ENT

(2) Program execution
Add: 3′2 1/2″ and 2′ 11 1/4″ Subtract: 2′ 11 7/8″

MODE: COMP FSE (for FIX) TAB2

Display	Key in	Notes
	0 STO A COMP	
	F R A C TITLE COMP	Title search
(Addition)		
F = ?	3 COMP	
I = ?	2 + 1 ÷ 2 COMP	
ANS 1 = 3.00	COMP	
ANS 2 = 2.50	COMP	

F = ?	2 COMP
I = ?	11 + 1 ÷ 4 COMP
ANS 1 = 6.00	COMP
ANS 2 = 1.75	COMP
	Answer: 6′ 1 3/4″

(Subtraction)

F = ?	(−) 2 COMP
I = ?	(−) 11 − 7 ÷ 8 COMP
ANS 1 = 3.00	COMP
ANS 2 = 1.88	
	Answer: 3′ 1 7/8″

Triangle Solutions

Solutions for all types of triangle problems can be developed using the law of sines and the law of cosines. These laws are ratios based on the trigonometric functions. The sides of a triangle are proportional to the sines of the angles they subtend and this fact is the basis of the law of sines.

Law of Cosines: $a^2 = b^2 + c^2 - 2bc \text{ CosA}$

Law of Sines: $\frac{a}{\text{SinA}} = \frac{b}{\text{SinB}} = \frac{c}{\text{SinC}}$

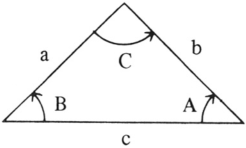


Figure 1

Program Notes:

The two types of triangle problems solvable by the law of cosines can be combined into a single program. The program first tests to see if the values of all three sides are given. If only two sides are given, the conditional statement jumps to the solution for the third side.

By using “VAR” values, the need for f()= is eliminated.

(1) Programming

MODE: AER

Display	**Key in**
TITLE ?	C O S I N E S ENT
M:	2ndF 1 D > 0 −Y→[] 2ndF 2, 2ndF 3, 2ndF 4 −Y→ [ ] −N→[ ] 2ndF 5, 2ndF 3, 2ndF 4 , ► −N→[] SUB:
1:	VAR a×b×c STO VAR D SUB:
2:	VAR COS^{-1} ((c^2 + b^2 − a^2) ÷ (VAR 2 VAR c×b SUB:
3:	VAR COS^{-1} ((c^2 + a^2 − b^2) ÷ (VAR 2 VAR a×c SUB:
4:	VAR COS^{-1} ((a^2 + b^2 − c^2) ÷ (VAR 2 VAR a×b SUB:
5:	VAR a $=\sqrt{\ }$(b^2 + c^2 − VAR2 VAR b×c×COS θ ENT

(2) Program execution

A yacht sails out to sea for 20 miles at the beginning of the day. On the return trip a strong current pushes the yacht 10° off course. After sailing for 19 miles on the return trip, how far is the yacht from its starting point?

MODE: COMP FSE(for FIX) TAB2 DRG(for DEG)

Display	**Key in**	**Notes**
	CA	
	C O S TITLE COMP	
a = ?	0 COMP	
b = ?	19 COMP	
c = ?	20 COMP	
θ = ?	10 COMP	
a = 3.54	COMP	Distance
ANS 2 = 68.67	COMP	Second angle
ANS 3 = 101.33		Third angle

A triangle measures 500×600×400, what are its angles?

Display	**Key in**
	CA COMP
a = ?	500 COMP
b = ?	600 COMP
c = ?	400 COMP
ANS 1 = 55.77	COMP
ANS 2 = 82.82	COMP
ANS 3 = 41.41	

Proof: 41.41 + 82.82 + 55.77 =
Answer: 180.00

The Law of Sines is used to solve triangle problems where one side and two angles is given or two sides and an angle opposite these sides is given.

(1) Programming

MODE: AER

Display	**Key in**
TITLE ?	S I N E ENT
M:	2ndF 1 D > 0 −Y→[] 2ndF 2, 2ndF 3, 2ndF 4 −Y→[] −N→[] 2ndF 5, 2ndF 3, 2ndF 4, ◣ −N→[] SUB:
1:	VAR a×b STO VAR D SUB:
2:	VAR β = SIN^{-1} (b×SIN θ ÷ a SUB:
3:	180−VAR θ − β STO VAR C SUB:
4:	VAR c = SIN VAR C×(VAR a ÷ SIN θ SUB:
5:	VAR b = a ÷ SIN θ)x SIN β ENT

(2) Program execution

A triangle has a 10-foot side and two of the angles are 30° and 50°. What are the values of the other two sides and angle?

MODE: COMP FSE (for FIX) TAB 2 DRG (for DEG)

Display	**Key in**
	CA
	S TITLE COMP
a = ?	10 COMP
b = ?	0 COMP
θ = ?	30 COMP
β = ?	50 COMP
b = 15.32	COMP
ANS 2 = 100.00	COMP
c = 19.70	

Two sides of a triangle are 20 and 30 feet and the adjacent angle is 30°. Solve for the third side and the other two angles.

Display	**Key in**
	COMP
a = ?	20 COMP
b = ?	30 COMP
θ = ?	30 COMP
β = 48.59	COMP
ANS 2 = 101.41	COMP
c = 39.21	

Moving Averages

A moving average takes the average of a window of data points. The “window” is a fixed number of points, so that as you move down a list, each new data point effectively pushes a data point out the other end. Moving averages are used in many types of business and economic studies to eliminate unusual single data points which would tend to obscure the overall trend. This program calculates a 3-item moving average.

Program Notes:
The answer for each period appears at the end of the statement. To create moving averages greater than 3, increase the variables in the opening equation, increase the divisor and add additional transferring of values statements.
A 4-item moving average would read:
f(A) = A + B + C + D) ÷ 3 STO Z C STO D
B STO C A STO B

(1) Programming

MODE: AER

Display	Key in
TITLE ?	M O V E - A V R COMP
M:	f()= A f()= A + B + C) ÷ 3 STO Z B STO C A STO B ⌴ Z ENT

(2) Program execution

Obtain a moving average for the following sequence:
5, 10, 15, 5, 20, 30, 10

MODE: COMP FSE (for FIX) TAB2

Display	**Key in**
	5 STO C 10 STO B
	M O V TITLE COMP
A = ?	15 COMP
ANS 1 = 10.00	COMP
A = ?	5 COMP
ANS 1 = 10.00	COMP
A = ?	20 COMP
ANS 1 = 13.33	COMP
A = ?	30 COMP
ANS 1 = 18.33	COMP
A = ?	10 COMP
ANS 1 = 20.00	

Quadratic Equations

The quadratic formula is used to solve quadratic equations when the roots cannot be factored. The equation is put in the form:

$$ax^2 + bx + c = 0$$

The solution of the roots takes the form:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

The portion of the root equation under the square root sign, $b^2 - 4\,ac$, is called the discriminant. When the discriminant is positive, there are two real roots. A zero value for the discriminant results in a single real root and a negative discriminant produces roots which are complex numbers.

A complex number is shown as a +bi, where i = −1. To solve for a negative discriminant, separate into b and i and solve using a positive square root.

Example: $x^2 + 2x + 3 = 0$ $(a = 1, b = 2, c = 3)$
Key in: $2^2 - 4\times 3 =$ Answer: -8
Convert $\sqrt{-8} = \sqrt{-4} \times \sqrt{2} = 2i\sqrt{2}$

$$x = \frac{-2 \pm 2i\sqrt{2}}{2\times 1} = -1 \pm i\sqrt{2}$$

(1) Programming

MODE: AER

Display	**Key in**
TITLE ?	Q U A D ENT
M:	2ndF 1 D > 0 − Y→[] 2ndF 2 −Y→[] −N→[] 2ndF 3, ► −N→[] SUB:
1:	VAR b^2 − VAR 4 VAR a×c STO VAR D SUB:
2:	VAR x_1 = (−) b + VAR √‾ D) ÷ 2 VAR a, x_2 = (−) b − VAR √‾ D) ÷ 2 VAR a SUB:
3:	VAR α = (−) b ÷ VAR 2 VAR a, β = VAR √‾ (−) D ÷ 2 VAR a ENT

(2) Program execution

Solve the following equations:
a) $2x^2 + 8x - 10$
b) $x^2 - .2x + .004$
c) $20x^2 + 9x + 3897$
d) $x^2 + x + 1$

MODE: COMP FSE (until FIX, SCI, ENG all disappear)

Display	Key in
	Q U A D TITLE COMP
b = ?	8 COMP
a = ?	2 COMP
c = ?	(−) 10 COMP
x1 = 1.	COMP
x2 = −5.	COMP
b = ?	(−).2 COMP
a = ?	1 COMP
c = ?	.004 COMP
x1 = 0.177459667	COMP
x2 = 0.022540333	COMP
b = ?	9 COMP
a = ?	20 COMP
c = ?	3897 COMP
α = −0.225	COMP
β = 13.95705467	COMP
	Roots are: −0.225 ±13.957 i
b = ?	1 COMP
a = ?	1 COMP
c = ?	1 COMP
α = −0.5	COMP
β = 0.866025404	
	Roots are: −0.5 ±0.866 i

Polynomials

The formula:
$p(x) = aoX^n + a_1X^{n-1} \ldots + a_{n-1}$

defines the basic polynomial p of degree n or less.

Program Notes:
The answers, e.g., ANS 1, will correspond to the values of X. X is initialized with 1 and increased by one by the last expression in the program:

(1) Programming

MODE: AER

Display	Key in
TITLE ?	P O L Y ENT
M:	AX Y^x 4 + BX Y^x 3 + CX^2 + DX + E STO Z N > X − Y→[] Z, X + 1 STO X ↰ − Y→[] ENT

(2) Program execution

For the polynomial, p, defined by:

$p(x) = 2x^4 - 8x^3 + 4x^2 - 2x + 1,$

calculate p (X) for X = 1 to 10.

MODE: COMP

Display	Key in
	10 STO N 2 STO A (−)8 STO B 4 STO C (−)2 STO D 1 STO E 1 STO X P O L Y TITLE COMP
ANS 1 = −3	COMP
ANS 2 = −19	COMP
ANS 3 = −23	COMP
ANS 4 = 57	COMP
ANS 5 = 341	COMP
ANS 6 = 997	COMP
ANS 7 = 2241	COMP
ANS 8 = 4337	COMP
ANS 9 = 7597	COMP
ANS 10 = 12381	

Series

Many functions cannot be keyed directly on the calculator. Approximations can be made with series. A series has an infinite number of terms. It is not possible to calculate every term in a particular series. The approximation improves with the number of terms included in the calculation.

Cos x

The cosines of an angle, given in radians, is equivalent to a series.

$$\mathrm{COS}x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \frac{x^8}{8!} \cdots\cdots\cdots\cdots$$

Program Note:
The second and third terms of the equation are repeated indefinitely until the value obtained by the equation less the "actual" cosine of X in radians is 0. The initial value of B is 1.

(1) Programming 1

MODE: AER

Display	**Key in**
TITLE ?	C O S - S E R I E S ENT
M:	B−(X Y^x (2C) ÷ (2C) n!) + (X Y^x (2C + 2) ÷ (2C + 2) n!) STO B C + 2 STO C B − COS X STO A A ≠ 0 –Y→[] B, ↰ –Y→[] –N→[] B, ◣ −N→[] ENT

(2) Program execution 1
Solve for 1 and 10.

MODE: COMP FSE (for FIX) TAB 9 DRG (for RAD)

Display	**Key in**
	1 STO X 1 STO B 1 STO C 0 STO A COS-SERIES TITLE COMP COMP COMP COMP

Answers 3 and 4 are the same 0.540302306

Internal digits cause the calculator to indicate that A = 0 is not reached until Answer 6.

	10 STO X 1 STO B 1 STO C 0 STO A

Answers 11 and 12 are −0.839071533

(3) Programming 2

Find the value of the definite integral:

$$\int_0^1 \mathrm{Sin}\, y^2\, dy = \frac{x^3}{3} - \frac{x^7}{7(3!)} + \frac{x^{11}}{11(5!)} - \frac{x^{15}}{15(7!)} \cdots\cdots\cdots\cdots$$

MODE: AER

Display	**Key in**
TITLE?	S I N - S E R I E S ENT
M:	E + X Y^x B ÷ (B×C n!) − X Y^x (B + 4) ÷ ((B + 4)×(C + 2)n!) STO E, C + 4 STO C B + 8 STO B B >1 −Y→[] ↰ −Y→[] ENT

(4) Program execution 2

Solve for X = 1, .01, and .567.

MODE: COMP

Display	**Key in**
	CA 1 STO X 3 STO B 1 STO C 0 STO E SIN-S TITLE COMP COMP COMP COMP

ANS 4 = 0.310268302

The "ANS" number multiplied by 2 indicates the number of terms used to obtain a consistent answer.

For X = .01 .01 STO X
Ans 1 = .000000333
For X = .567 .567 STO X
Ans 2 = 0.060314322

(5) Programming 3
A definite integral commonly used in statistics:

$$\int_{0}^{x} e^{-y^2}dy = x - \frac{x^3}{3} + \frac{x^5}{5(2!)} - \frac{x^7}{7(3!)} \cdots\cdots\cdots\cdots$$

MODE: AER

Display	**Key in**
TITLE?	E − SERIES ENT
M:	Z − (X Yx B ÷ (B×C n!)) + X Yx (B + 2) ÷ ((B + 2)×(C + 1) n!) STO Z + X, B + 4 STO B C + 2 STO C C > 1 –Y→[] ↰ –Y→[] ENT

(6) Program execution 3
Solve for X = 1 and 2

MODE: COMP

Display	**Key in**
	CA
	1 STOX 3 STO B 1 STO C
	0 STO Z
	E-SERIES TITLE
	COMP COMP COMP COMP
	COMP COMP COMP

ANS 7 = 0.746824133
For X = 2
ANS 12: = 0.882081391

Matrices

A matrix is a rectangular array of numbers. The horizontal lists are called rows and the verticals, columns. A particular element in a matrix is identified by row and column numbers:

A (Row#, Column#)

A 3×3 matrix is:

$$\begin{vmatrix} a1 & b1 & c1 \\ a2 & b2 & c2 \\ a3 & b3 & c3 \end{vmatrix}$$

and its "determinate" is calculated as shown in the equation below.

(1) Programming 1

MODE: AER

Display	**Key in**
TITLE?	MATRIX ENT
M:	VAR a1×b2×c3 + a2×b3×c1 + a3×b1 × c2 − a1×b3×c2 − a3×b2×c1 − a2×b1 ×c3 ENT

(2) Program execution 1
Solve for:

$$\begin{vmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{vmatrix}$$

MODE: COMP FSE (for FIX) TAB 3

Display	**Key in**
	MATRIX TITLE COMP
a1 = ?	1 COMP
b2 = ?	5 COMP
c3 = ?	9 COMP
a2 = ?	4 COMP
b3 = ?	8 COMP
c1 = ?	3 COMP
a3 = ?	7 COMP
b1 = ?	2 COMP
c2 = ?	6 COMP
ANS 1 = 0.000	Change c3 to 10
	Answer: −3.000

The inverse of a 3×3 matrix is defined as:

$$A^{-1} = \begin{vmatrix} \alpha 1 & \alpha 4 & \alpha 7 \\ \alpha 2 & \alpha 5 & \alpha 8 \\ \alpha 3 & \alpha 6 & \alpha 9 \end{vmatrix}$$

Program Note:
The program exceeds the capacity of a single line. Three subroutine lines are used at the end. Add to the matrix equation above:

(3) Programming 2

MODE: AER

Display	**Key in**
	STO D, VAR b2×c3 − b3×c2) ÷
	VAR D, VAR a3×c2 − a2×c3) ÷
	VAR D, VAR a2×b3 − a3 ×b2)
	÷ VAR D, VAR b3×c1 − b1×c3)
	÷ VAR D, VAR a1×c3 − a3×c1)
	÷ VAR D, VAR a3×b1 − a1×b3)
	÷ VAR D, 2ndF 1, 2ndF 2, 2ndF 3
	SUB:
1:	VAR b1×c2 − b2×c1) ÷ VAR D
	SUB:
2:	VAR a2×c1 − a1×c2) ÷ VAR D
	SUB:
3:	VAR a1×b2 − a2×b1) ÷ VAR D
	ENT

(4) Program execution 2

Take the matrix:

	a	b	c
1	3	14	6
2	3	−4	8
3	3	24	17

and determine the determinate and the inverse.

MODE: COMP FSE (for FIX) TAB 3

Display	**Key in**
	MATRIX TITLE COMP
a1 = ?	3 COMP
b2 = ?	(−) 4 COMP
c3 = ?	17 COMP
:	: (Enter the rest of variables)
:	:
c2 = ?	8 COMP

ANS 1 = −654.000 (determinate)

Continue pressing COMP to get the nine answers that make the inverse, which is:

$$A^{-1} = \begin{vmatrix} 0.398 & 0.144 & -0.208 \\ 0.041 & -0.050 & 0.009 \\ -0.128 & 0.046 & 0.083 \end{vmatrix}$$

Three-Variable Linear Equations

The basic format of 3-variable linear equations is:

$$\begin{aligned} a_1x + b_1y + c_1z &= d_1 \\ a_2x + b_2y + c_2z &= d_2 \\ a_3x + b_3y + c_3z &= d_3 \end{aligned}$$

The values of x, y, and z take the forms:

$$x = \frac{\begin{vmatrix} d_1 & b_1 & c_1 \\ d_2 & b_2 & c_2 \\ d_3 & b_3 & c_3 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}} \qquad y = \frac{\begin{vmatrix} a_1 & d_1 & c_1 \\ a_2 & d_2 & c_2 \\ a_3 & d_3 & c_3 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}}$$

$$z = \frac{d_1 - a_1x - b_1y}{c_1}$$

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	L I N E A R ENT
M:	After the program for a matrix determinate (i.e., the first program in the "Matrices" section), add : VAR STO D, 2ndF 1 2ndF 2␣G÷ D STO E, H ÷ D STO F, VAR z = d1 − a1×VAR E − VAR b1×VAR F) ÷ VAR c1 SUB:

1: VAR d1×b2×c3 + d2×b3×c1 +
d3×b1 × c2 − d1×b3×c2 −
d3×b2×c1 − d2×b1 x c3 VAR
STO G SUB:

2: VAR a1×d2×c3 + a2×d3×c1 +
a3×d1× c2 − a1×d3×c2 −
a3×d2×c1 − a2×d1 ×c3 VAR
STO H ENT

(2) Program execution

Calculate X, Y, and Z for:

$$X + Y + Z = 9$$
$$6X + 6Y - Z = 17$$
$$14X - 7Y + 2Z = 42$$

MODE: COMP FSE (for FIX) TAB 3

Display	**Key in**	**Note**
	LINEAR TITLE COMP	
Fill in the values for the denominator of x and y:		
ANS 1 = −147.000	COMP	
d1 = ?	9 COMP	
d2 = ?	17 COMP	
d3 = ?	42 COMP	
ANS 2 = 2.735	COMP	
ANS 3 = 0.980	COMP	Value of X
z = 5.286		Value of y

Proof: (Use any of the three equations)

Key in: 14×2.735 − 7×.98 + 2×5.286 =

Answer: 42.002

Random Number Generation

A widely used formula for generating random numbers is:

$$X_{n+1} = \text{FRAC } (\pi + x_n)^5$$

The seed, Xn, can be varied between 0 and 1 to give many random number sequences.

Program Notes:

The program produces numbers between 0 and 1,000.

The range of numbers can be varied by changing the amount A is multiplied by, at the end.

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	R A N D O M ENT
M:	FRAC ((A + π)Y^x 5) STO A A>0 –Y→[] 1000 A, ↰ –Y→[] ENT

(2) Program execution

MODE: COMP FSE (for FIX) TAB 0

Display	**Key in**
	.5 STO A
	RANDOM TITLE COMP
ANS 1 = 408	COMP
ANS 2 = 583	COMP
ANS 3 = 189	COMP
ANS 4 = 681	COMP
ANS 5 = 729	COMP
⋮ ⋮	

Statistics

In the statistical mode, the store memories U to Z are loaded with values which are retained even if the mode switch is changed to COMP or AER. This capability can be used in the programming of many statistical applications.

The value in each store memory is:

Store Memory	**Contents**
Z	n
Y	Σx
X	Σx^2
W	Σxy
V	Σy
U	Σy^2

Correlations

A perfect correlation between two values in a regression analysis results in an r equal to 1 (−1 is a perfect negative correlation). In other words, by knowing the value of one variable you can predict with 100% accuracy the value of the other variable. The further the value of r is from 1 or −1, the less reliable will your predictions be. The following table can be used as a set of definitions of the values of the correlation coefficient.

	Value of r	Call it
Positive Correlation	+0.80 to 1.00	Extra High
	+0.60 to 0.80	High
	+0.40 to 0.60	Moderate
	+0.20 to 0.40	Low
	−0.20 to +0.20	Nil
	−0.20 to −0.40	Low

Negative	−0.40 to −0.60	Moderate
Correlation	−0.60 to −0.80	High
	−0.80 to −1.00	Extra High

Linear Regression

Is weight a good predictor of longevity among men 65 years of age? In 1950, 10 men each 6 feet tall, were selected for an experiment to determine if their weight effected their life span.

Sample	1	2	3	4	5	6	7	8	9	10
Age at death	72	67	69	85	91	68	77	74	70	82
Weight at age 65	185	226	200	169	170	195	175	174	198	172

MODE: COMP STAT FSE (for FIX) TAB 3
Key in
72 (x,y) 185 DATA
67 (x,y) 226 DATA
⋮ ⋮ ⋮

Continue for the remainder of the above table.
r −0.793 (correlation)
r indicates a relative high negative correlation. A higher weight indicates a shorter life span. To graph the regression line, a and b are used.

a	321.929 (y-axis)
b	−1.795 (slope)

Predict the age of death of a 6-foot man weighing 190 pounds in 1950.

Key in: 190 (x')
Answer: 73.495 years

To reach age 90, what should a man's weight be in 1960?

Key in: 90 (y')
Answer: 160.371 pounds

To reach age 150, what should a man's weight be? Obviously, the answer will make no sense, indicating the danger of carrying a straight-line extrapolation too far.

Non-Linear Regression

The measure of reliability of a straight-line correlation (r) is given by the equation:

$$r = \frac{n\Sigma(xy) - \Sigma(x)\Sigma(y)}{\sqrt{(n\Sigma x^2 - (\Sigma x)^2) \times (n\Sigma y^2 - (\Sigma y)^2)}}$$

The value of r and the correlation curve may be determined for first order non-linear relationships (Exponential, Logarithmic, and Power) by adapting to the linear regression format by the use of natural logarithms.

Exponential

Data in an exponential format fits the curve:

$$y = ae^{bx}$$

Exponential data is entered by taking the natural log of the y value and the equation becomes:

$$\ln y = \ln a + bx$$

Estimated results are obtained by raising the result exponentially. The value in register a will be ln a.

Prove values obtained in the STAT mode are correct. The coefficients a and b are computed from:

$$b=\frac{\Sigma x_1 \ln y_1-\frac{1}{n}(\Sigma x_1)(\Sigma \ln y_1)}{\Sigma x_1^2-\frac{1}{n}(\Sigma x_1)^2}$$

$$a=\exp\frac{\Sigma \ln y_1}{n}-b\frac{\Sigma x_1-i}{n}$$

Program Note:
All of the values stored in the STAT mode are employed.

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	E X P - R E G ENT
M:	W − Zx^{-1} YV) ÷ (X−Zx^{-1} Yx^2) STO B, VAR a = e^x VAR ((V − BY) ÷ Z), VAR r = VAR √‾ ((W − Zx^{-1} YV) x^2 ÷ ((X − Yx^2 ÷ Z) x (U − V x^2 ÷ Z ENT

(2) Program execution

Determine the equation, coefficient of correlation, and estimated y values for x = 9.2 and −2.6, for the following values:

x	0.5	1.6	3.6	7.9	8.7
y	8	13.2	52.9	1008	2201

MODE: COMP STAT FSE (for FIX) TAB 3

Key in

CA

.5	(x,y)	LN	8	DATA
1.6	(x,y)	LN	13.2	DATA
3.6	(x,y)	LN	52.9	DATA
7.9	(x,y)	LN	1008	DATA
8.7	(x,y)	LN	2201	DATA

	Answer
(r)	0.999
(a)	1.583
(b)	0.687
e^x (a) =	4.870

Obtain estimated values of Y

	Answer
9.2 (y')	7.906
e^x 7.906 =	2713.515
(−) 2.6 (y')	−0.204
e^x(−).204 =	0.815

Proof:

MODE: COMP (Use 2ndF STAT until STAT disappears)

Display	**Key in**	
ANS 1 = 0.687	COMP	value of b
a = 4.868	COMP	
r = 0.999	COMP	

The equation is therefore of the form:

$y = 4.868e^{0.687x}$

Logarithmic

The curve fits the equation:

$$y = a + b \ln X$$

In each of the equations (a, b, and r), the value of X becomes ln x.

Determine the equation, value of r, and estimated value of y for $x = 8$ and 40, for the following set of values:

x	6	9	20	26
y	18.6	50.1	80.7	92.8

MODE: COMP STAT FSE (for FIX) TAB 3
Key in
CA

LN	6	(x,y)	18.6	DATA
LN	9	(x,y)	50.1	DATA
LN	20	(x,y)	80.7	DATA
LN	26	(x,y)	92.8	DATA

	Answer:
(r)	0.988
(a)	−62.657
(b)	48.115

The equation is: $y = -62.657 + 48.115 \ln x$

LN 8 (y')	37.394
LN 40 (y')	114.832

Power Curves

Data fitting a power curve takes the form:

$$y = ax^b$$

To transform this equation into the linear format, it is written:

$$\ln\ y = b\ \ln\ x + \ln\ a$$

Data is placed in the equation for a, b, and r as ln x and ln y.

Determine the equation, r, and estimated values of y for x = 50 and 1,000 for the following sets of data:

x	2	10	20	100
y	50	124000	551×10^4	592×10^7

MODE: COMP STAT FSE (for FIX) TAB 3

Key in

CA

LN	2	(x,y)	LN	50	DATA
LN	10	(x,y)	LN	124000	DATA
LN	20	(x,y)	LN	551 Exp 4	DATA
LN	100	(x,y)	LN	592 Exp 7	DATA

		Answer:
r		0.999
a	0.769 e^x . 769 =	2.158
b		4.774

The equation is: $y = 2.158 \times 4.774$

	Answer:
LN 50 (y')	19.445
e^x 19.445 =	
FSE FSE	278.52×10^6
LN Exp 3 (y')	33.746
e^x 33.746 =	452.586×10^{12}

Curve Fitting

Using the techniques of regression analysis, the type of curve best describing a phenomenon can be chosen and analyzed. Up to 10 pairs of data can be stored in the EL-5150 store memories (A to T) for analysis. Based on the following data, predict the population of El paso, Texas, in the year 2000 and describe this city's population growth from 1950 to 1978.

Year (x)	Population
1950	130435
1960	276687
1970	322261
1978	400741

MODE: COMP

Key in

50	STO	A	130435	STO	B
60	STO	C	276687	STO	D
70	STO	E	322261	STO	F
78	STO	G	400741	STO	H

MODE: COMP STAT FSE (for FIX) TAB 3

Key in

For linear:

CA

A	(x,y)	B	DATA
C	(x,y)	D	DATA
E	(x,y)	F	DATA
G	(x,y)	H	DATA

(r) = 0.977

For exponential:

```
CA
A   (x,y)       LN   B   DATA
C   (x,y)       LN   D   DATA
E   (x,y)       LN   F   DATA
G   (x,y)       LN   H   DATA
```

r = 0.942

For logarithms:

```
CA
LN   A   (x,y)   B      DATA
LN   C   (x,y)   D      DATA
LN   E   (x,y)   F      DATA
LN   G   (x,y)   H      DATA
```

(r) = 0.985

For power:

Key in

```
CA
LN  A   (x,y)  LN  B        DATA
LN  C   (x,y)  LN  D        DATA
LN  E   (x,y)  LN  F        DATA
LN  G   (x,y)  LN  H        DATA
```

(r) = 0.959

Logarithmic gives the best fit.

a = −2120044.303

b = 578530.522

The growth of population in El Paso, Texas, is described by a logarithmic curve:

$$y = -2120044.303 + 578530.522 \ln x$$

For the year 2000 (x = 100) population will be:

Key in: LN 100 y' Answer: 544187

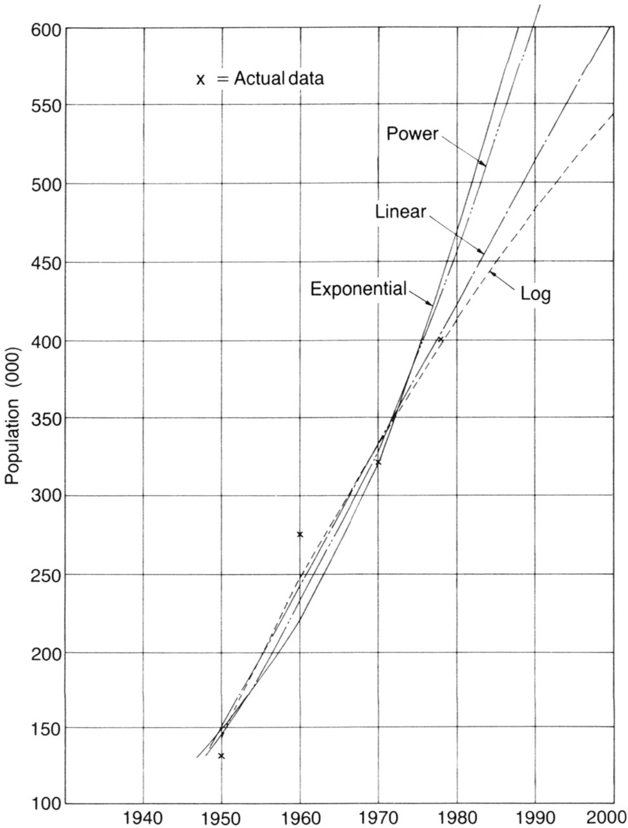

x = Actual data
Power
Linear
Exponential
Log
Population (000)
600
550
500
450
400
350
300
250
200
150
100
1940
1950
1960
1970
1980
1990
2000

Figure 2

"t" Test

A small sample in statistics usually means less than 30. Small samples are particularly important where the data is very expensive or difficult to obtain or a test requires destruction of a product.

The t-distribution is close to the normal distribution and permits checking of a hypothesis even with a small sample.

$$t = \frac{X - \mu o}{S/\sqrt{n}}$$

where X = sample mean
s = sample standard deviation
n = sample size
μo = required population mean

The "t" test can be programmed using the store memories.

Let u = μo

$$t = \frac{X - \mu o}{s/\sqrt{n}} - \frac{\frac{\Sigma X}{n} - \mu o}{\sqrt{\frac{\Sigma X^2 - n(\Sigma X/n)^2}{n(n-1)}}}$$

$$= \frac{\frac{Y}{Z} - u}{\sqrt{\frac{X - Z(Y \div Z)^2}{Z(Z-1)}}}$$

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	VAR t − t e s t ENT
M:	VAR t = VAR Y ÷ Z − VAR μ) ÷ √‾ ((VAR X − Z×(Y ÷ Z)x^2) ÷ (Z×(Z −1 ENT

(2) Program execution

Test the X data in the linear regression example on age. First, key in the statistical data on page 23 in STAT mode. Assume that 70 is the average life span.

MODE: COMP
Key in
COMP
u = 70 COMP
Answer: t = 2.147

Checking the "t" probability levels table, for a sample size of 10, the data will be accurate more than 95% of the time.

A sample of 20 units of a particular size transistor used until it fails. Mean-life of the sample is found to be 8,400 hours with a standard deviation of 785 hours. A buyer of transistors requires a mean-life of 8,100 hours. Will the buyer be safe with a 5% level of confidence if these transistors are purchased?

Key in: 8400 − 8100) ÷ (785 ÷ $\sqrt{20}$ =
Answer: 1.709

From the table, the value for t at 5% confidence level is 1.729. We use the sample size (n) -1 as the degrees of freedom.

Since the t calculated at 1.709 is less than 1.729, the buyer can conclude that the transistors purchased could be from a population with a mean lifetime equal to or greater than 8,100 hours 95% of the time.

Chi-Square Test

The x^2-Test is used to determine if a set of data when compared to an ideal or predetermined distribution of that data has a variance from probability or some preset expectation. The formula for the test is:

$$X^2 = \frac{\Sigma(O - E)^2}{E}$$

where O = Observed Frequency
E = Expected Frequency

The hypothesis is rejected if the X^2 statistic falls in the rejection region of the X^2 distribution.

The proportion of adult females (over age 21) in society is 52% of total adults. The number of female workers earning above $20,000/year in three companies was established. Analyzing the data, is the difference between the actual proportions compared to the expected proportions based on population significant?

Expected Frequency of Employees by Sex

MODE: COMP FSE (fox FIX) TAB 0
Key in: .52 STO A

Company	Entry	Female	Male
A	10000 A =	5200	4800
B	5650 A =	2938	2712
C	3290 A =	1711	1579

The table below indicates the actual number with the expected below in parentheses. Each cell will be calculated in the x^2 calculation.

	Company A	Company B	Company C
Female	3100	2900	1800
	(5200)	(2938)	(1711)
Male	6900	2750	1490
	(4800)	(2712)	(1579)
Total	10000	5650	3290

Let E = E (Expected Frequency)
D = O (Observed Frequency)

Program Notes:
The use of a counter controls the number of requests for data to the value of the number of observations (N).

(1) Programming

MODE: AER

Display	**Key in**
TITLE ?	C H I – SQ. ENT
M:	f()= OE f()= O – E) x^2 ÷ E STO A + G STO G 1 + X STO X X ≠ N –Y→[] ↰ –Y→[] -N→[] G, ◣ –N→[] ENT

(2) Program execution

MODE: COMP FSE (for FIX) TAB 2

Key in

6 STO N 0 STO X 0 STO G (Data initializing)
CHI TITLE COMP (Title search)

O = 5200 COMP	E = 3100 COMP
2938	2900
1711	1800
4800	6900
2712	2750
1579	1490
	Ans: 1 = 2072.45

The $X^2_{0.05}$ column in the table represents the dividing line which cuts off 5% of the right tail of the distribution. The degree of freedom is one less than the number of sample proportions being tested.

In the above example, the df is 2 and $X^2_{0.05} = 5.991$. The value obtained is significantly higher, indicating that the difference between what was expected and what was actually happening was due to factors other than chance.

Physics

Launching a Projectile

Launching a projectile into space requires a high initial velocity. The number of seconds to reach a specific height can be calculated if the initial velocity is known. A simplified version of the equation is:

$$H = V_0 t - \frac{1}{2} g t^2$$

where H = height (feet) of the object after t seconds
Vo = initial velocity (feet/second)
t = time (seconds)
g = gravitational acceleration (32 feet/sec/sec)

$$\frac{1}{2} g = 16$$

A launch occurs with an initial velocity of 900 feet per second. How long will it take to reach 10,000 feet (approximately 2 miles)?

$$1000 = 900t - 16t^2$$
$$16t^2 - 900t + 10000 = 0$$

Find the quadratic formula solution previously programmed.

MODE: COMP FSE (for FIX) TAB 4

Display	**Key in**
	QUAD TITLE (Title search)
	COMP
b = ?	(−) 900 COMP
a = ?	16 COMP
c = ?	10000 COMP
x 1 = 41.0097	COMP
x 2 = 15.2403	STO A

Proof: $16\,A\,x^2 - 900A + 10000 =$
Answer: 0.0000

Orbiting

Determining the velocity of an object in orbit at any point in its orbit is a problem that is applicable to many fields. In space research, the velocity of a spacecraft orbiting the earth or of a planet moving around the sun may be calculated. The equation for velocity is:

$$v = \sqrt{2GM\left(\frac{1}{r} - \frac{1}{2a}\right)}$$

where r = radial distance at a given point on an elliptical orbit
a = mean distance from the central object
G = universal gravitational constant
M = mass of central object

This equation assumes that the mass of the orbiting object is insignificant compared to that of the central object.

(1) Programming

MODE: AER

Display	**Key in**
TITLE	O R B I T ENT
M:	VAR v = $\sqrt{\ }$ (VAR 2G VAR m×(rx^{-1} − (VAR 2 VAR a) x^{-1} ENT

(2) Program execution 1

At a distance of 8×10^8 kilometers from the sun, at what speed is the planet Jupiter orbiting?

$r = 8 \times 10^8$, $a = 7.784 \times 10^8$, $M = 1.992 \times 10^{33}$

MODE: COMP FSE (for FIX) TAB4

Display	**Key in**
	6.668 Exp (−)23 STO G
	ORBIT TITLE COMP
m = ?	1.992 Exp 33 COMP
r = ?	8 Exp 8 COMP
a = ?	7.784 Exp 8 COMP
V = 12.7053 (Kilometers/sec)	

If the distance were 6×10^8 kilometers, what would the speed be?

	COMP
m = ?	COMP
r = ?	6 Exp 8 COMP
a = ?	COMP
V = 16.4959 (Kilometers/sec)	

The eccentricity of an ellipse is a measure of its closeness to a circle. The greater the eccentricity, the more elongated will be the ellipse (less like a circle).

Compare the percent differences between the maximum and minimum differences from the sun for Venus and Mars. The sun occupies one focus of a planetary ellipse and the distance between a planet and the sun is:

$$r=\frac{a(1-e^2)}{1-e\mathrm{COS}\,\eta}$$

a = semimajor axis of the ellipse = mean distance from the sun

e = eccentricity

η = polar angle in radians

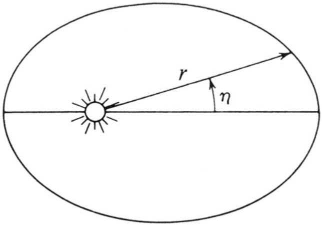


Figure 3

The angle is measured in radians ($\pi = 180^\circ$) and the unit of angle for calculations will be RAD instead of DEG. It can be seen that the maximum distance from the sun is $\eta = 0$ and the shortest distance is $\eta = \pi$.

(1) Programming 2

MODE: AER

Display	**Key in**
TITLE?	DIST-SUN ENT
M:	VAR r = a (VAR 1 − VAR ex^2)) ÷ (VAR 1 − VAR e COS n ENT

(2) Program execution 2

Planet	Eccentricity of Orbit	Mean Distance from the Sun (Miles)
Venus	0.006783	67.24×10^6
Earth	0.016718	92.96×10^6
Mars	0.093387	141.62×10^6

MODE: COMP FSE (for SCI) DRG (for RAD)

Display	**Key in**	**Notes**
For Venus:	DIST-SUN TITLE COMP	
a = ?	67.24 Exp 6 COMP	
e = ?	6.783 Exp (−) 3 COMP	
n = ?	π COMP	Initial angle
r = 6.6784E 07	STO F	Minimum distance
	COMP	
a = ?	COMP	
e = ?	COMP	
n = ?	0 COMP	Change angle
r = 6.7696E 07	STO A	Maximum distance
	A − F) ÷ A × 100 =	

Answer: 1.35%

For Venus, there is a 1.35% difference between maximum and minimum distance from the sun.

For Mars:

	COMP	
a = ?	141.62 Exp 6 COMP	
e = ?	.093387 COMP	
n = ?	π COMP	
r = 1.2839E 8	STO F	Minimum distance
	COMP	
a = ?	COMP	
e = ?	COMP	
n = ?	0 COMP	
r = 1.5485E 8	STO A	Maximum distance
	A − F) ÷ A × 100 =	

Answer: 17.08% (shown as 1.708E 01)

For Mars, there is a 17.08% difference between the maximum and minimum distances from the sun. The substantially greater difference between the maximum distances from the sun for Mars versus Venus can be accounted for by the greater eccentricity of the elliptical orbit of Mars.

At what angle will earth's distance from the sun be the same as its mean distance from the sun? Substituting in the original equation:

$$92.96 \times 10^{6} = \frac{92.96 \times 10^{6}(1 - e^{2})}{1 - e\mathrm{COS}\,\eta}$$

The mean values cancel each other and:

$$1 - e \cos\eta = 1 - e^{2}$$
$$\mathrm{Cos}\,\eta = 16.718 \times 10^{-3}$$

MODE: COMP DRG (for RAD) FSE (for floating decimal)
Key in : $\cos^{-1}$ 16.718 Exp (−) 3 =

Answer: 1.554077548 radians (about π/2)

In satellite motion, the orbiting of one object around another, the effects of acceleration and the gravitational force must be taken into consideration. The gravitational force is an inverse square central force. This continuous force acting on a satellite in orbit changes its magnitude and direction as the satellite moves.

The orbit can be approximated by breaking the satellite's flight into a series of small steps.

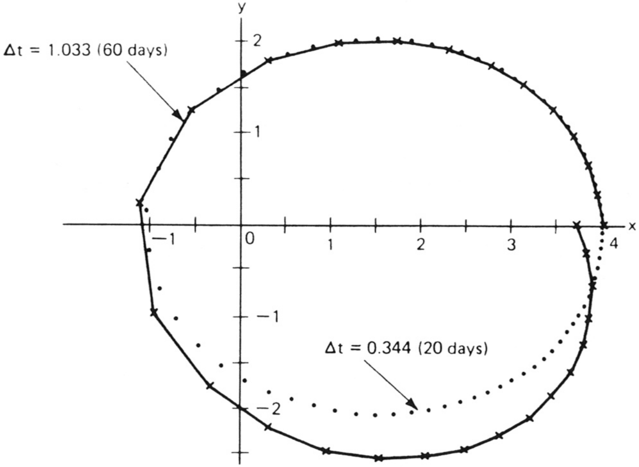


Figure 4

A comet has an initial distance from the sun of 4 Astronomical Units (A.U.) and an initial velocity of 2 A.U./year. Plot the orbit.

The applicable parameters are:

Orbital Period = 2π = 6.28 = time units for one circumference

G = universal gravitational constant

M = mass of central body

C = $-$GM = -1 = proportionality constant which is negative when the central force is attractive

n = 2 = dependence on center-to-center distance by the central body and the body moving by it

t = 60 days = 60/365×6.28 = 1.033

r = distance from the central body

a = acceleration

V = velocity

Vyo = 2 A.U./6.28 = 0.3183

x = 4 A.U. = initial distance from the sun

The applicable equations are:

$$\text{Distance} = r = \sqrt{x^2 + y^2}$$

$$\text{Acceleration} = ax\Delta t + Cr^{-(n+1)}\,x\Delta t$$

$$ay\Delta t + Cr^{-(n+1)}\,y\Delta t$$

$$\text{Velocity} = \text{New } Vx = \text{Old } Vx + ax\Delta t$$

$$\text{New } Vy = \text{Old } Vy + ay\Delta t$$

* Based on material from the book: COUNTDOWN ON PROGRAMMABLE CALCULATORS, by R. Eisberg & W. Hyde, Dilithium Press, Portland, OR., 1979.

$$\text{Location} = \text{New } x = \text{Old } x + Vx\Delta t$$

$$\text{New } y = \text{Old } y + Vy\Delta t$$

Program Notes:

The first answer gives the × position and the second the y position.

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	COUNT ENT
M:	C× $\sqrt{\quad}$ (Xx^2 + Yx^2) Y^x (−) (N+1)×T×(1−Z) STO I 0 STO Z IX + V STO V IY + W STO W VT + X STO X, WT + Y STO Y, A + T STO A ENT

(2) Program execution

MODE: COMP FSE (for FIX) TAB 2

Key in

2 STO N 0 STO V (−) 1 STO C 60 ÷ 365 × 6.28 STO T 2 ÷ 6.28 STO W .5 STO Z 4 STO X 0 STO Y 0 STO A COMP

```
ANS 1 (x)    ANS 2 (y)    ANS 3 (t)
  3.97         0.33          1.03
  3.87         0.65          2.06
  3.70         0.96          3.10
  3.46         1.26          4.13
  3.15         1.52          5.16
  2.75         1.75          6.19
  2.28         1.93          7.23
  1.71         2.02          8.26
  1.04         2.00          9.29
  0.28         1.80         10.32
 −0.53         1.28         11.36
 −1.13         0.25         12.39
 −0.95        −0.96         13.42
 −0.36        −1.74         14.45
  0.30        −2.20         15.48
  0.93        −2.45         16.52
  1.51        −2.55         17.55
  2.02        −2.54         18.58
```

This orbit will fail to close when plotted on graph paper. (See Fig. 4.) The reader should try a smaller Δt (20 days) to get a perfect ellipse.

Moment of Inertia

The moments of inertia (Ixx, Iyy and Ixy) about any two *x* and y axes for n number of elements are programmable on the EL-5150. The transfers of each of these inertias to the Xc.g. and Yc.g. (center of gravity) axes of the element set can also be computed. The number of elements that can accommodated is virtually unlimited.

The input information required is:

1. *x* and y distances to each element
2. corresponding element sizes
3 element $\Sigma \bar{I}xx$ and $\Sigma \bar{I}yy$

Formula:

1. $\bar{x} = \dfrac{\Sigma Ax}{\Sigma A}$
2. $\bar{y} = \dfrac{\Sigma Ay}{\Sigma A}$
3. $Ixy = \Sigma Axy - \bar{y}\Sigma Ax - \bar{x}\Sigma Ay + \bar{x}\,\bar{y}\Sigma A =$
   Product of inertia about x and y axis
4. $Iyy = \Sigma Ax^2 + \Sigma \bar{I}yy - \Sigma(AY)^2 \div A =$
   Moment of inertia about y axis
5. $Ixx = \Sigma Ay^2 + \Sigma \bar{I}xx - \Sigma(Ay)^2 \div A =$
   Moment of inertia about x axis
   Radius of Gyration
6. $xx = \sqrt{\dfrac{Ixx}{A}}$
7. $yy = \sqrt{\dfrac{Iyy}{A}}$

where n = number of elements

c.g. = center of gravity or centroid of the element set

Let: $\Sigma\bar{I}xx$ = Total for all the elements of each element's moment of inertia about its own Xc.g. axis

$\Sigma\bar{I}yy$ = Total for all the elements of each element's moment of inertia about its own Yc.g. axis

Program Notes:

The program takes advantage of the following capabilities of EL-5150.

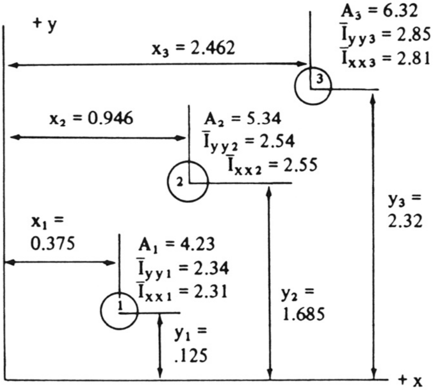


Figure 5

1. Data may be accumulated in the STAT mode for later use in COMP mode.

$Z = \Sigma A$
$Y = \Sigma Ax$
$X = \Sigma Ax^2$
$W = \Sigma Axy$
$V = \Sigma Ay$
$U = \Sigma Ay^2$

2. In addition to storing data in thex and y registers a third set of corresponding data (in this case Area) can be stored in the “n“ register. “n” represents the number of samples and on most calculators is limited to whole numbers. The EL-5150 permits the storage of values in “n” which have fraction components.

The answers will be given as follows:

Value	Calculator
$\bar{x}$	x =
$\bar{y}$	y =
Ixy	i =
Iyy	a =
yy	ANS 6
xx	ANS 7

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	MOMENT ENT
M:	VAR x = VAR Y ÷ Z, VAR y = VAR V ÷ Z, VAR i = VAR W − VAR y VAR Y − VARx VAR V + VARx × y VAR Z, VAR a = VARX + VAR iyy − VARYx^2 ÷ Z, VAR b = VAR U + VAR ixx − VAR Vx^2 ÷ Z, √‾‾ VAR (a ÷ VAR Z, √‾‾ VAR (b ÷ VAR Z ENT

(2) Program execution

MODE: COMP STAT

Key in		Comment
.375 (x,y)	.125×4.23 DATA	x1, y1, A1
.946 (x,y)	1.685×5.34 DATA	x2, y2, A2
2.462 (x,y)	2.32×6.32 DATA	xn Yn, An

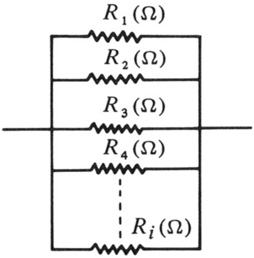
MODE: COMP FSE (for FIX) TAB 3

COMP x = 1.397
COMP y = 1.522
COMP i = 11.018
COMP iyy = 2.34 + 2.54 + 2.85
COMP a = 20.403
COMP ixx = 2.31 + 2.55 + 2.81
COMP b = 20.092
COMP ANS 6 = 1.133
COMP ANS 7 = 1.124

ELECTRONICS

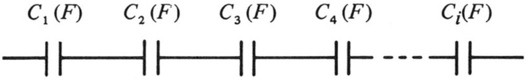
Parallel Resistance and Series Capacitance

Total resistance for resistors in parallel is given by:



$$R_0 = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \cdots + \frac{1}{R_i}}$$

The same formula applies to capacitances in series:



$$C_0 = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4} + \cdots\cdots + \frac{1}{C_i}}$$

Figure 6

The program which can be used with any number of items (N) uses:

C = Value of resistance or capacitance
R = Accumulated values of 1/C's

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	P A R A − R E S ENT
M:	f()= C f()= R + C x^{-1} STO R 1 + X STO X X ≠ N −Y→[] ↰ −Y →[] −N→[] R x^{-1} , ◣ −N→[] ENT

For resistances in parallel of 5, 28, 133, and 74, what is the equivalent resistance?

MODE: COMP FSE (for FIX) TAB 3

Display	**Key in**
	PARA-RES TITLE
	0 STO X 4 STO N 0 STO R
	(Data initialization)
	COMP
C = ?	5 COMP
C = ?	28 COMP
C = ?	133 COMP
C = ?	74 COMP

ANS 1 = 3.895 (ohms)

Four capacitances in series have values of 1, 2, 3, and 4. What is the equivalent capacitance?

Display	**Key in**
	0 STO X 4 STO N 0 STO R
	COMP
C = ?	1 COMP
C = ?	2 COMP
C = ?	3 COMP
C = ?	4 COMP

ANS 1 = 0.480 (μf)

Series Reactance and Impedance

Reactance is referred to as a “frequency-sensitive” ohm. For the capacitor it is called capacitive reactance and has the unit Xc in ohms. For inductors it is called inductive reactance and has the unit XL in ohms. Capacitive resistance is inversely proportional to frequency while inductive reactance is directly proportional to frequency.

Impedance, Z, is the opposition to current flow caused by reactive and resistive components in series, parallel or series-parallel combinations. The program solves for Z and its phase angle (θ) for series RC, RL, and RCL circuits

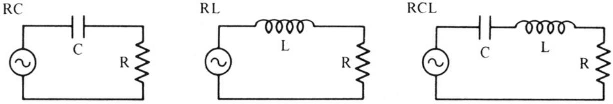


Figure 7

The formula for three types of circuits are:

RC: $Z = \sqrt{R^2 + (1/2\,\pi fC)^2}$ $\theta = \tan\text{-}1 \dfrac{[1/2\pi fC\,]}{R}$

RL: $Z = \sqrt{R^2 + (2\pi fL)^2}$ $\theta = \tan^{-1}[2\pi fL/R]$

RCL: $Z = \sqrt{R^2 + [(2\pi fL) - (1/2\pi fC)]^2}$
$\theta = \tan^{-1}[((2\pi fL) - (1/2\pi fC))/R]$

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	IMP-RC ENT
M:	f()= RCF f() = $\sqrt{\ }$ (Rx^2 + (1 ÷ 2 πFC)x^2, VAR θ VAR = TAN^{-1} ((1 ÷ 2π FC) ÷ R ENT
TITLE?	IMP-RL ENT
M:	f()= RLF f()= $\sqrt{\ }$ (Rx^2 + (2πFL)x^2, VAR θ VAR = TAN^{-1} (2πFL ÷ R ENT
TITLE?	IMP-RCL ENT
M:	f()=RCLF f()= $\sqrt{\ }$ (Rx^2 + ((2πFL) − 1 ÷ (2πFC))x^2, VAR θ VAR = TAN^{-1} ((2πFL − 1 ÷ (2πFC)) ÷ R ENT

(2) Program execution

Obtain the Impedance and Phase angle for the following circuits:

RC: $R = 200$ $C = 1E\text{-}11$ $F = 5E7$
RL: $R = 200$ $L = 1$ $F = 60$
RCL: $R = 5$ $C = 5E\text{-}05$ $L = .025$ $F = 50$
MODE: COMP FSE (for FIX) TAB 2 DRG (for DEG)

Display	**Key in**
	IMP-RC TITLE
	COMP
R = ?	200 COMP
C = ?	Exp (−) 11 COMP
F = ?	5 Exp 7 COMP
ANS 1 = 375.93 (Ω)	COMP
$\theta = 57.86$(°)	
	IMP-RL TITLE
	COMP
R = ?	200 COMP
L = ?	1 COMP
F = ?	60 COMP
ANS 1 = 426.76 (Ω)	COMP
$\theta = 62.05$(°)	
	IMP-RCL TITLE
	COMP
R = ?	5 COMP
C = ?	5 Exp (−) 5 COMP
L = ?	.025 COMP
F = ?	50 COMP
ANS 1 = 56.03 (Ω)	COMP
$\theta = -84.88$(°)	

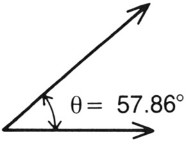


Figure 8

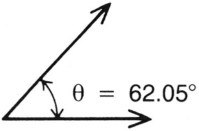


Figure 9

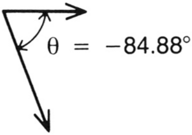


Figure 10

Parallel Reactance and Impedance

The impedance of a parallel RC, RL, or RCL circuit must be less than the minimum value in any one of the parallel branches. The Z_T of a parallel RC, RL, or RCL circuit does not equal that of a series circuit because of the basic relationship of current and voltage in parallel circuits.

The program solves for the phase angle of total current with respect to resistor current. Resistor current is the reference at zero degrees. The impedance is solved by the relationship:

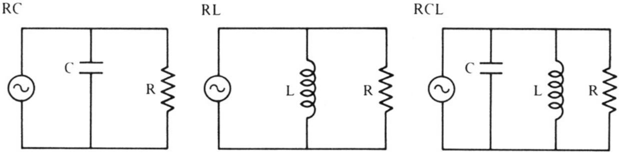


Figure 11

$Z_T \angle 0° = E/I_T \angle 0°$ which is Ohm's Law for AC circuits.

The assumed voltage for RC and RL circuits is equal to the absolute value of Xc or X_L.

The formulas that apply to these three circuits are:

$$\text{RC: } I_R = |Xc| / R \qquad Z = |Xc| / I_T \qquad I_T = \sqrt{(I_R^2 + 1)}$$
$$\theta = \tan^{-1} (1/I_R)$$
$$\text{RL: } I_R = |X_L| / R \qquad Z = |X_L| / I_T \qquad I_T = \sqrt{(I_R^2 + 1)}$$
$$\theta = \tan^{-1} - (1/I_R)$$
$$\text{RCL: } Z = |Z| = 1 / \sqrt{1/R^2 + (1/\omega L - \omega C)^2}$$
$$\theta = \tan^{-1} R\,(1/\omega L - \omega C)$$

(1) Programming

MODE: AER

Display	Key in
TITLE?	P. IMP-RC ENT
M:	f()= RCF f()= ABS (1 ÷ 2πFC) STO X ÷ R STO I X ÷ √ (Ix^2 + 1, VAR θ VAR = TAN^{-1} (1 ÷ I ENT
TITLE?	P. IMP-RL ENT
M:	f()= RLF f()= ABS (2πFL) STO X ÷ R STO I X ÷ √ (I x^2 + 1), VAR θ VAR = TAN^{-1} (−) 1 ÷ I ENT
TITLE?	P.IMP-RCL ENT
M:	f()= RCLF f()= 1 ÷ 2πFL − 2πFC) STO A ABS (1 ÷ √ (1 ÷ Rx^2 + Ax^2)), VAR θ VAR = TAN^{-1} RA ENT

(2) Program execution

Obtain the Impedance and Phase angle for the following circuits:

RC: R = 15 C = 8E-04 F = 10
RL: R = 20 L = .318 F = 10
RCL: R = 8 C = 5E-07 L = .04 F = 60

MODE: COMP FSE (for FIX) TAB 2

Display	Key in
	P.IMP-RC TITLE
	COMP
R = ?	15 COMP
C = ?	8 Exp (−)4 COMP
F = ?	10 COMP
ANS 1 = 11.98 (Ω)	COMP
θ = 37.02(°)	

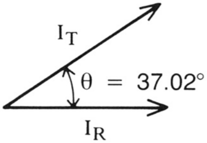


Figure 12

	P.IMP-RL TITLE
	COMP
R = ?	20 COMP
L = ?	.318 COMP
F = ?	10 COMP
ANS 1 = 14.14 (Ω) COMP	
θ = −45.04(°)	

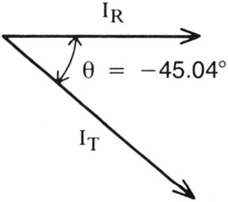


Figure 13

	P.IMP-RCL TITLE
	COMP
R = ?	8 COMP
C = ?	5 Exp (−)7 COMP
L = ?	.04 COMP
F = ?	60 COMP
ANS 1 = 7.07 (Ω) COMP	
θ = 27.88(°)	

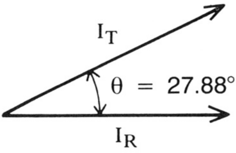


Figure 14

Multiple Feedback Bandpass Filter

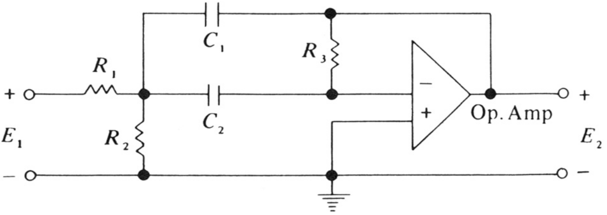


Figure 15

In the multiple feedback filter illustrated, the op-amp is connected in the inverting mode and:

$$Q > \sqrt{Go/2}$$

The formulas for the resistances are:

$$R_1 = Q/(2\pi fGoC) \qquad R_2 = Q/(2\pi fC(2Q^2 - Go))$$
$$R_3 = 2R_1Go$$

The center frequency can easily be shifted. The center frequency gain and band width remain constant with the new value of R because:

$$R' = R_2 (f/f')^2$$

Program Notes:
The program is set up to build a table of resistances for different frequencies. The increment of frequency used is 100Hz. The increment can be varied by changing the value in the first statement in the program.

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	B A N D ENT
M:	F + 100 STO F, Q ÷ 2π FGC STO R, VAR r_2 VAR = Q ÷ (2πFC×(2Qx^2 − G, VAR r_3 VAR = 2 RG ENT

(2) Program execution

The center frequency gain for the circuit is 1.25 and Q is 3.8. The capacitors are selected from standard values; use .022 mf.

MODE: COMP FSE (for ENG) TAB 3

Key in

0 STO F 1.25 STO G 3.8
STO Q .022 Exp (−) 6 STO C
COMP

	(X 10^3)		
F (ANS 1)	R_1 (ANS 2)	R_2 (ANS 3)	R_3 (ANS 4)
100	219.923	9.949	549.808
200	109.962	4.975	274.904
300	73.308	3.316	183.269
400	54.981	2.487	137.452
500	43.985	1.990	109.962
600	36.654	1.658	91.635
700	31.418	1.421	78.544
800	27.490	1.244	68.726
900	24.436	1.105	61.090
1000	21.992	0.995	54.981

Chemistry

Ideal Gas Equation

Most gases behave as predicted by the ideal gas equation. The equation states that the volume of a gas will vary directly with the number of gas molecules and with absolute temperature, and inversely with pressure. It is usually written:

$PV = nRT$ where n = number of gas molecules
R = ideal gas constant
$= 0.0821 \dfrac{\text{liter-atm.}}{\text{mole}^\circ \text{K}}$
T = absolute temperature $273 + t^\circ$ centigrade

Program to calculate each of the four variables, P, V, n, and T.

a) $P = n\ RT/V$
b) $V = n\ RT/P$
c) $T = PV/nR$
d) $n = PV/RT$

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	G A S – P ENT
M:	VAR p = n VAR R×(273 + VAR t) ÷ v ENT
TITLE?	G A S – V ENT
M:	VAR v=n VAR R×(273 + VAR t) ÷ p ENT
TITLE?	G A S – T ENT
M:	VAR t = p×v ÷ n VAR R – 273 ENT

TITLE?	GAS-N ENT
M:	VAR n = p×v ÷ VAR (R×(273 + VAR t ENT

(2) Program execution

Calculate:

a) Volume of .5 moles of oxygen at 15°C and 700 mm Hg pressure.
b) Weight of nitrogen in a 75.0 liter-tank at 20°C and a pressure of 100 atm.
c) Pressure of 10 moles of ethane at 15°C in a 10,000 ml tank.

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**	**Notes**
	.0821 STO R	
	GAS-V TITLE	
	COMP	
n = ?	.5 COMP	
t = ?	15 COMP	
p = ?	700×.001315 COMP	P converted to Atm
v = 12.84 (liters)		
	GAS-N TITLE	
	COMP	
p = ?	100 COMP	
v = ?	75 COMP	
t = ?	20 COMP	
n = 311.78	x 28* = 8729.84 (grams)	
(moles of N^2)	* molecular weight	

```
                  GAS-P  TITLE
                  COMP
n  =  ?           10  COMP
t  =  ?           15  COMP
v  =  ?           10  COMP
p  =  23.64  (Atm)
```

Solar Energy

The most important characteristic of a solar collector is the percent of solar radiation transmitted by the glass to the absorbing material (water). The radiation transmitted is a function of the glass's refractive index (for ordinary glass = 1.52) and the angle of incidence of the sun.

The reflectance from a plate of glass varies from the incidence angle (i). The fresnel equation calculates the reflection of a beam and the simultaneous radiation through one surface of a transparent solid.

$$\mathrm{RHO} = \frac{1}{2}\left[\frac{\sin^2(i - r_a)}{\sin^2(i + r_a)} + \frac{\tan^2(i - r_a)}{\tan^2(i + r_a)}\right]$$

r_a is the angle of refraction and is calculated by:

$\sin r_a = \sin i / r_1\text{-coll}$
$r_1\text{-coll} = \text{refractive index} = 1.52$

In the program I = i and R = r_a

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	S O L A R ENT
M:	I + 10 STO I SIN^{-1} (SIN I ÷ 1.52) STO R SIN (I − R))x^2 ÷ (SIN (I + R)) x^2 + (TAN (I − R))x^2 ÷ (TAN (I + R))x^2) ×50, I ≠ 90 −Y→[] ↰ −Y→[] −N→[] ◣ −N→[] ENT

(2) Program execution

MODE: COMP FSE (for FIX) TAB 2 DRG (for DEG)

Display	**Key in**
	0 STO I SOLAR TITLE

Key in COMP for each increment of I. Each "ANS" number multiplied by 10 corresponds to the value of I.

Angle of incidence (degrees)

Percent Reflected = RHO

I	10	20	30	40	50	60	70	80	90
R	4.26	4.29	4.41	4.85	6.06	9.25	17.47	39.09	100

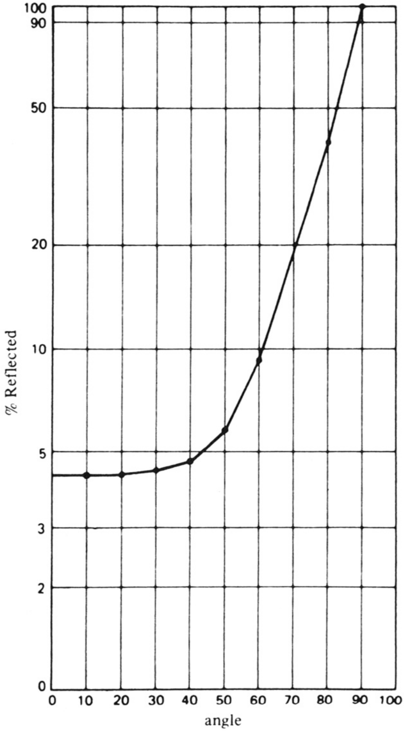


Figure 16

Pressure Loss

Head is the pressure consumed (or "lost") in forcing a fluid along against the resistances caused by the conduits through which the fluid flows. The equation for the head lost by friction in a water pipe is:

$$H = \left[0.0126 + \frac{0.01739 - 0.1087\,d}{\sqrt{V}}\right] \times \frac{L}{d} \times \frac{v^2}{2g}$$

where H = loss of head due to friction (meters)
V = velocity inside the pipe (m/sec)
L = length of pipe (meters)
g = gravitational constant ($g = 90.8\text{m/sec}^2$ and $2g = 19.6$)
d = inner diameter of the pipe (meters)

Head is also lost when the fluid passes through various fittings. This loss is:

$$H = \frac{kv^2}{2g}$$

where k = coefficient for fitting loss

Program Notes:

If there are fittings, the value of nk will be the number of each type of fitting multiplied by the K value of each. The use of A, B, and C to represent the 3 constants in the equation helps to conserve the number of program steps used.

(1) Programming

MODE: AER

Display	Key in
TITLE?	H E A D ENT
M:	VAR h = VAR A + (B − C × VAR d) ÷√v)×(l ÷ d)×(vx^2 ÷ VAR 19.6) VAR + nk×vx^2 ÷ VAR 19.6 ENT

(2) Program execution

MODE: COMP FSE (for floating decimal point)

Display	Key in
	.0126 STO A .01739 STO B .1087 STO C HEAD TITLE COMP
d = ?	.01 COMP
v = ?	.5 COMP
l = ?	5 COMP
nk = ?	5 + 2 × .4 COMP

h = 0.301377064 (Loss in meters)

Uniformly Loaded Wood Beams*

Using a specific wood species and grade, determine the number of beams required for a given load. The depth required due to shearing stress and bending stress must be less than the width of the beam.

* Based on material and programs submitted by: George Mason Clark, Architect A.I.A. C.S.I., Professor Emeritus, The Ohio State University

The following quantities will be calculated:

1) The total load on the beam in pounds W = wL, where w = load in pounds per foot and L = span length

2) deflection $= \Delta = L \div$ fractional span deflection
3) required moment of inertia $I = 5WL^3 \div (384E\Delta)$
4) required depth $= \sqrt[3]{12\ I \div B}$ where B = width of trial beam
5) required bending depth $= \sqrt{\dfrac{72\ CWL}{8FB}}$

6) size factor adjustment for beams exceeding 12" in depth

$$D' = \frac{D}{(\frac{12}{D})^{0.11}} = \frac{D^{1.11}}{12^{0.11}}$$

7) original w (re-calculated)
where

E = Modulus of elasticity of wood species and grade, psi
F = Allowable fiber stress in bending for wood species, grade and section, psi (f)
w = Load, alternately expressed in pounds per foot (original entry) and in pounds (for calculation, converted as ANS 1)
L = Span, feet (center to center of simple supports, face to support of fixed supports)
H = Denominator of fraction expressing allowable deflection, inches as function of span in feet
A = Coefficient expressing support and continuity configuration of beam at maximum deflection location, including conversion of span to inches
C = Ratio expressing support and continuity configuration of beam at maximum bending moment location, with simple beam as 1
B = Width of trial beam (or beams used together), Inches

The allowable depth is calculated based on the unit shearing stress equation:

$$V = A = \frac{3V}{2 \times \text{area}} = \frac{3V}{2 \times \text{Depth} \times B}$$

$$\text{Depth} = \frac{3V}{2BA} = \frac{3w}{HBA}$$

where
V = 1/2 W and H is substituted for 4 in the denominator
W = w
K = Reaction coefficient based on support
a = Allowable horizontal shearing stress, PSI
Various A, C and K coefficients

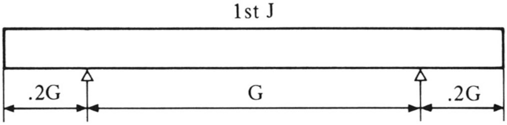


Figure 17

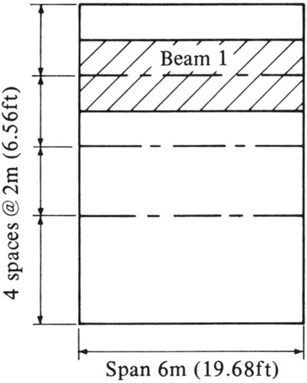
(1) Programming

MODE: AER

Display	**Key in**
TITLE?	W O O D ENT
	f ()= E F L H A C B f()= VAR w
	VAR L STO M, L ÷ H STO D,
	AML Y^{x} 3 ÷ DE STO I, $\sqrt[3]{\quad}$
	(12 I ÷ B, $\sqrt{\quad}$ (9 MLC ÷ BF)
	STO D, .761 D Y^{x} 1.11, 3M ÷
	VAR (k VAR B×VAR a ENT

(2) Program execution

Example 1:
How many hemlock fir beams of construction grade are required for a span of 6m (19.68 ft), if the load is 50 pounds per square foot? The beams to be used are 2×12's and four widths will initially be used with a beam spacing of 2m (6.56 ft).



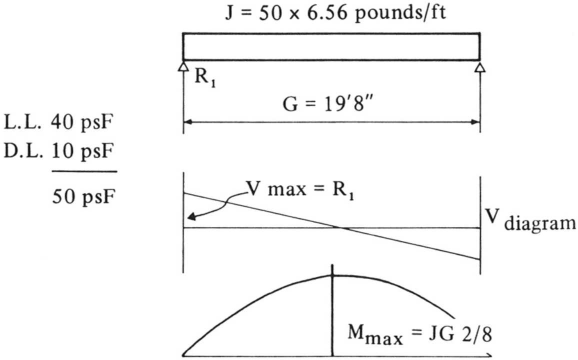


Figure 18

MODE: COMP FSE (for FIX) TAB2

Display	**Key in**	**Notes**
	W O O D TITLE	
	COMP	
E = ?	1.4 Exp 6	psi
	COMP	
F = ?	1200 COMP	psi

L = ?	19.68 COMP	feet
H = ?	20 COMP	1/240 span in inches (×12)
A = ?	5 ÷ 384)×12 Y^x 3 COMP	
C = ?	1 COMP	Simple Span
B = ?	6 COMP	4 nominal 2" beams B 1 1/2" used together
w = ?	50×6.56 COMP	pounds per foot
ANS 1 = 6455.04	COMP	Total load on beam, pounds
ANS 2 = 0.98	COMP	Allowable deflection for beam span being analyzed, inches
ANS 3 = 803.59	COMP	Required moment of inertia to not exceed allowable deflection, inches^4
ANS 4 = 11.71	COMP	Required depth based on required moment of inertia (I) and trial width (B), (new D, inches)
ANS 5 = 12.60	COMP	Required depth based on allowable bending stress and support configuration of beam/width/span being analyzed (new D, inches)

ANS 6 = 12.67	COMP	Shape factor - revised depth as increased for depths greater than 12" (new D, inches)
K = ?	4 COMP	Reaction coefficient
a = ?	75 COMP	psi
ANS 7 = 10.76		Disregard this answer

The required depth has to be less than 11.5 inches (2×12 actual depth). Try 5 widths:

Display	**Key in**	**Notes**
	COMP	
E = ?	:	
:	:	Change only here
B = ?	7.5 COMP	5 beams + 1 1/2"
:	:	
ANS 1 = 6455.04	COMP	
ANS 2 = 0.98	COMP	
ANS 3 = 803.59	COMP	
ANS 4 = 10.87	COMP	Deflection
ANS 5 = 11.27	COMP	Bending
ANS 6 = 11.20	COMP	Shape (bending governs)

Now the shear is checked.

K = ?	COMP	
a = ?	COMP	
ANS 7 = 8.61		Required depth based on allowable shearing stress a and reaction coefficient K, inches

Bending governs and 5 beams are acceptable.

Example 2:

Dense select structural beams of the S.Y. Pine species are to be used for a two-continuous span beam. What width is required?

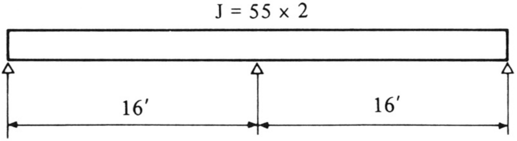


Figure 19

Display	**Key in**	Notes
E = ?	1.76 Exp 6 COMP	psi
F = ?	2100 COMP	psi
L = ?	16 COMP	inches
H = ?	30 COMP	1/360 span in inches × 12
A = ?	12.79 COMP	
C = ?	1 COMP	
B = ?	1.5 COMP	inches
w = ?	110 COMP	
ANS 1 = 1760.00	COMP	pounds-total, load/span

ANS 2 = 0.53	COMP	Allowable deflection
ANS 3 = 98.23	COMP	Required I
ANS 4 = 9.23	COMP	Required depth, deflection (2×10)?
ANS 5 = 8.97	COMP	Required depth, bending (2 x 10)?
ANS 6 = 8.69	COMP	Required depth, shape (2 x 10)?
k = ?	3.2 COMP	
a = ?	110 COMP	
ANS 7 = 10.00		Required depth (inches)

The required depth governs the choice of width and therefore 2 ×12 is required. Since horizontal shear is critical, choose lesser grade (lower F) to bring required D values closer to equal.

Trenching

An expression of the work produced by an excavator used for trenching applications is the machine's trenching rate expressed in lineal feet per day. Earthmoving production is measured by:

$$L = \frac{E}{B \times F} \times T$$

where:
L = lineal feet of trench per day
E = cubic yards per hour
B = compacted cubic yards of soil per lineal foot of trench
F = soil swell factor
T = hours per day

(1) Programming 1

MODE: AER

Display	**Key in**
TITLE?	T R E N C H ENT
M:	f()= EB FT f()= E ÷ BF)×T ENT

(2) Program execution 1

An excavator will produce 250 cubic yards per hour. A trench survey shows that the trench contains 2 cubic yards per foot with a soil swell factor of 30%. What production rate can be expected in a 7 1/2-hour work day?

MODE: COMP FSE (for FIX) TAB 0

Display	**Key in**
	TRENCH TITLE COMP
E = ?	250 COMP
B = ?	2 COMP
F = ?	1.3 COMP
T = ?	7.5 COMP

ANS 1 = 721 (feet/day)

(3) Programming 2

The contractor may also be responsible for preparing the trench and lowering the pipe in a sewer construction job. To determine total production, the pipe installation time is calculated and is added to the time required for other procedures. The latter must be estimated by the contractor.

$$\text{Actual feet of pipe laid /day} = \left[\frac{\text{Pipe length}}{\text{trenching rate/hr}} + \text{other time}\right]^{-1}$$

$$\times 60 \times \text{hours/day} \times \text{efficiency}$$

MODE: AER

Display	**Key in**
TITLE?	P I P E ENT
M:	f()= P E B F O A T f()= 60 ÷ (60 PBF ÷ E + O))×AT) STO H VAR afd VAR = INT (HP ÷ P)×P ENT

(4) Program execution 2

An excavator can produce 450 lineal cubic yards in an hour. Calculate the trenching production for a contractor if the average cross section of the trench is 3.5 BCY per foot; the swell factor for sandy clay soil is 26% and it takes 12 minutes to install each 20-foot length of pipe after the trench has been opened. Job efficiency is 80 % in an 8-hour work day.

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**
	PIPE TITLE COMP
P = ?	20 COMP
E = ?	450 COMP
B = ?	3.5 COMP
F = ?	1.26 COMP
O = ?	12 COMP
A = ?	.8 COMP
T = ?	8 COMP
afd = 320.00 (feet)	

Will increasing work efficiency to 90% have a major effect?

Press COMP to leave all previous inputs as above except A = .9 COMP

Display	**Key in**	
	COMP	
A = ?	.9 COMP	
:	:	
:	COMP	
afd = 360	÷ 320 = 1.13	13% increase in production

Earthmoving

The cubic yards of bank material carried by a machine is determined by the weight of the load divided by the bank density. Production is estimated by calculating the number of complete trips a unit makes in an hour.

$$\text{Production} = \text{load/cycle} \times \text{cycles/hour} = \frac{\text{weight of load}}{\text{bank density}} \times \frac{60}{\text{cycle time}}$$

Weight of load = average weight of loaded unit – weight haul unit empty

Cycle time = wait time + load time + delay time + haul time + dump time + return time

Program Notes:
Use seconds as minutes in the conversions.

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	E A R T H ENT
M:	X − 1 STO X X > 0 -Y→[] VAR t VAR →D.MS STO A + B STO B -Y→[] -N→[] B → DEG STO C VAR w − e) ÷ d)×VAR (60 ÷ C, ► -N→[] ENT

(2) Program execution

A study of a tractor scraper revealed the following time:
Wait = 17 seconds Load = 40 seconds Delay = 15 seconds Haul = 4 minutes 15 seconds Dump = 30 seconds Return = 2minutes 6 seconds

The empty haul unit weighs49,600 lb and the average loaded unit weighs 91,500 lb. If the bank density is 3,215 lb/cubic yard, what is the hourly production?

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**	**Notes**
	0 STO B	
	7 STO X	
	EARTH TITLE	
	COMP	
t = ?	.17 COMP	
ANS 1 = 0.10	COMP	
t = ?	.40 COMP	
ANS 1 = 0.34	COMP	
t = ?	.15 COMP	
ANS 1 = 0.43	COMP	
t = ?	4.15 COMP	
ANS 1 = 4.52	COMP	
t = ?	.3 COMP	
ANS 1 = 4.70	COMP	

t = ?	2.06 COMP	
ANS 1 = 6.73	COMP	Cycle time (minutes)
w = ?	91500 COMP	
e = ?	49600 COMP	
d = ?	3215 COMP	
ANS 1 = 108.15		Bank cubic yards/hour

Business

Break-Even analysis

"Break-even" is a business technique used to determine the quantity of a product where total costs will equal variable costs plus fixed costs. Fixed costs are depreciation, light, power, utilities, rent, insurance, administrative salaries, and others. Variable costs are materials and labor. The number of units required to reach the break-even point is:

Quantity = Fixed Cost/ Price – Variable Cost/ Unit

It is possible to use supply and demand curves to determine the price. Supply curves measure the willingness of manufacturers to provide product at different prices. Demand curves reflect the willingness of consumers to buy at different prices.

The supply and demand charges can alternatively be used to determine the price in the break-even equation. The basic equation for these curves is $P = A + BX$.

F = Fixed Cost
P = Price
V = Variable cost/unit

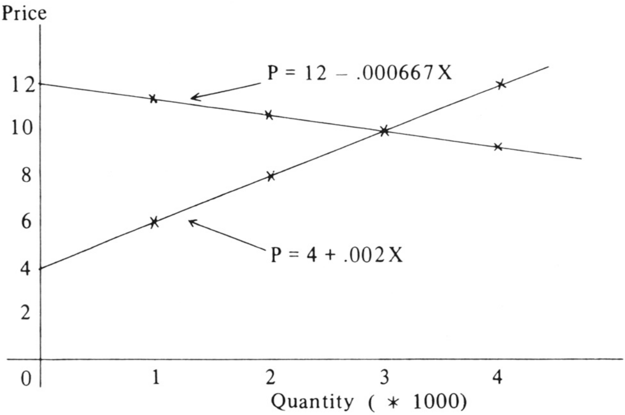


Figure 20

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	B R E A K ENT
M:	2ndF 2, VAR f ÷ (ps − v) STO VAR A, − VAR x, 2ndF 1, f ÷ (pd − v) STO VAR B, VAR − x SUB:
1:	VAR pd = a + b × x SUB:
2:	VAR ps = c + d × x ENT

(2) Program execution

The supply curve for a particular product is: P = 4 + .002X. The demand curve is: P = 12 − .000667X. The fixed cost is $10,000 and the variable cost is $6.00. Determine break-even quantities based on the supply and demand curves. Use supply and demand quantities of 2,000 in each case.

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**	**Notes**
	BREAK TITLE COMP	
c = ?	4 COMP	Using Supply Curve
d = ?	.002 COMP	
x = ?	2000 COMP	Quantity
ps = 8.00	COMP	Price
f = ?	10000 COMP	Fixed cost
v = ?	6 COMP	Variable cost
ANS 2 = 5000.00	COMP	Break-even quantity
ANS 3 = 3000.00	COMP	Difference between break-even quantity and supply curve quantity
a = ?	12 COMP	Using Demand Curve
b = ?	(−).000667 COMP	
pd = 10.67	COMP	Price
ANS 5 = 2143.16	COMP	Break-even quantity
ANS 6 = 143.16	COMP	Difference between break-even quantity and demand curve quantity

Try a quantity of 3000:

Display	**Key in**	**Notes**
c = ?	COMP	
d = ?	COMP	
x = ?	3000 COMP	
ps = 10.00	COMP	
f = ?	COMP	
v = ?	COMP	
ANS 2 = 2500.00	COMP	
ANS 3 = −500.00	COMP	Demand quantity at $10 is 500 more than required to break even.
a = ?	COMP	
b = ?	COMP	Supply curve
pd = 10.00	COMP	
ANS 5 = 2500.63	COMP	
ANS 6 = −499.37		Same answer as for demand curve

This is the equilibrium point of the two curves. When the equilibrium price is higher than required to break even, the investment situation is favorable.

Depreciation

The assets of a business (vehicles, equipment, buildings, etc.) are "used up" or worn out over a period of years causing a decrease in value. This decrease in the value of an asset is called depreciation. Depreciation is usually based on historical costs (the actual cost of an item). Current or replacement costs in most cases will be higher and consequently the depreciation taken is too low. Depreciation lower than replacement costs causes the overstatement of the current value of capital assets, earnings, and taxes.

Accelerated depreciation is used to compensate for the replacement cost problem. Changing the rate of depreciation does not change cash flow, except if taxes are considered.

The continuation of increasing costs due to inflation in the indefinite future strengthens the case for accelerated depreciation. The incentive to increase cash flow in the short term is greatest when the revenues available this year will buy more than the same amount of revenues generated one, two, or three years later.

The most commonly used techniques of depreciation are straight line, declining balance, and sum-of-years' digits.

Straight-Line Depreciation

To depreciate an asset using straight-line depreciation (a constant decrease in value, or constant-balance method) requires establishing the current value (C), the salvage or residual value (S), and the life of the asset in years (Y).

Formula for Straight-Line Depreciation:

$$D = (C - S)/Y$$

where

C = Current Value
S = Salvage Value
Y = No. of Years

Straight-line depreciation has been altered by the IRS tax codes and is called the Accelerated Cost Recovery System (ACRS):

3-year property		5-year property		10-year property	
1st year	25%	1st year	15%	1st year	8%
2nd year	38%	2nd year	22%	2nd year	14%
3rd year	37%	3rd-5th	21%	3rd year	12%
				4th-6th	10%
				7th-10th	9%

(1) Program execution

MODE: AER

Display	**Key in**
TITLE?	D E P – A C R S ENT
M:	C – S STO A X > 3 –Y→[] 2ndF 2
	– Y→[] – N→[] 2ndF 1, ►
	–N→[] SUB:
❶:	VAR y1 = VAR . 25A, VAR y2 =
	VAR . 38A, VAR y3 = VAR . 37A
	SUB:
❷:	VAR y1 = VAR . 15A, VAR y2
	VAR . 22A, VAR Y345 = VAR
	. 21A ENT

(2) Program execution

For an automobile with a cost of $12,000 and salvage value of $1,000, calculate the three amounts of depreciation.

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**	**Notes**
	3 STO X 12000	
	STO C	
	1000 STO S	
	DEP-ACRS TITLE	
	COMP	
y1 = 2750.00	COMP	1st year amount
y2 = 4180.00	COMP	2nd year amount

y3 = 4070.00	3rd year amount

What would ACRS depreciation be on a five-year basis?

Display	**Key in**	
	5 STO X	
	COMP	
y1 = 1650.00	COMP	
y2 = 2420.00	COMP	
y345 = 2310.00		3rd-5th year amount

Declining Balance Depreciation

One accelerated depreciation method, declining balance, requires specifying the initial book value or current book value (C), the life of the asset in years (Y), and the acceleration factor (A). Double declining or 200% is the most common acceleration factor.

The formula for declining balance depreciation of a business asset is shown below. The book value (C) is multiplied by the acceleration factor (A) and then divided by the life of the asset in years (Y).

Year 1 $D_1 = C \times A/100/Y$
Year 2 $D_2 = (C - D1) \times A/100/Y$
Year 3 $D_3 = (C - (D1 + D2)) \times A/100/Y$
etc. ......

where, D = Depreciation
C = Book value
A = Acceleration factor (%)
Y = Years

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	D E P − D E C ENT
M:	X + 1 STO X Y >= X −Y→[] 2ndF 1, VAR d + VAR D STO D ↰ −Y→[] −N→[] ◣ −N→[] SUB:
❶:	VAR d = VAR C − D)×A ÷ Y ENT

(2) Program execution

The depreciable fixed assets required for a proposed box manufacturing production line consists primarily of forming machinery. The machinery has a cost of $100,000, a usable life of five years and a salvage life of $20,000.

MODE: COMP FSE (for FIX) TAB 0

Display	**Key in**
	0 STO X 0 STO D 100000 STO C 200 ÷ 100 STO A 5 STO Y DEP-DEC TITLE COMP
d = 40000	COMP
d = 24000	COMP
d = 14400	COMP
d = 8640	COMP
d = 5184	

Sum of the Year's Digits Depreciation

Another method for computing accelerated depreciation is called sum of the year's digits. With this method an even "write off" of an asset's value may be obtained initially. This method requires a salvage value, thus improving the "Balance Sheet" with respect to assets and net worth during the later years.

To compute depreciation using this method, the asset's value less salvage value is multiplied by a ratio of the number of years remaining divided by the sum of the years asset's life. For example, if an asset has a six-year life, the sum is represented by:

$$6 + 5 + 4 + 3 + 2 + 1 = 21$$

The formula is: $D = C \times (Y/S)$

where D = Depreciation
C = Current book value
Y = Remaining years of life
S = Sum of the year's digits

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	D E P - S U M ENT
M:	Y > 0 −Y→[] 2ndF 1, VAR d + VAR T STO T Y − 1 STO Y ↰ −Y →[] −N→[]T, ► −N→[] SUB:
1:	VAR d = VAR C − D)×(Y ÷ S ENT

(2) Program execution

In the previous example use the sum-of-the year's digits technique with a six-year life.

MODE: COMP FSE (for FIX) TAB2

Display	**Key in**
	21 STO S 6 STO Y 0 STO D 80000 STO C 0 STO T DEP-SUM TITLE COMP
d = 22857.14	COMP
d = 19047.62	COMP

d = 15238.10 COMP
d = 11428.57 COMP
d = 7619.05 COMP
d = 3809.52 COMP
ANS 7 = 80000.00 Total

Interest Calculations

The basic formula for the future value of money:

$$FV = PV\,(1 + i)^n$$

can be placed into a series of programs to yield any of the four values.

PV = p = Present Value
FV = f = Future Value
i = i = Interest Rate per Period ÷ 100
n = n = Number of Periods

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	F U T V A L ENT
M:	VAR f = p × VAR (1 + VAR i) Y^x n ENT
TITLE?	P R E S V A L ENT
M:	VAR p = f ÷ VAR (1 + VAR i) Y^x n ENT
TITLE?	I N T R A T ENT
M:	VAR i = n $\sqrt[x]{\quad}$ (f ÷ p) − VAR 1 ENT
TITLE?	I N T P E R ENT
M:	VAR n = LN (f ÷ p) ÷ LN (i + VAR 1 ENT

(2) Program execution

$150,000 will be invested for five years. At an annual rate of 9.25% compounded quarterly, what is its future value?

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**	**Notes**
	FUT TITLE	
	COMP	
p = ?	150000 COMP	
i = ?	.0925 ÷ 4 COMP	Adjusted for quarterly
n = ?	5×4 COMP	Adjusted for quarterly
f = 236954.63		Future value

At an interest rate of 10%, a $200,000 loan has a balloon payment of $30,000 at the end of the loan period (15 years). What is the present value of the balloon payment?

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**	
	TITLE (keep pressing until PRESVAL appears)	
	COMP	
f = ?	30000 COMP	
i = ?	.1 COMP	
n = ?	15 COMP	
p = 7181.76		Present value

To raise its sales level to 1,000,000 units per year in 5 years, a company now producing 100,000 units must grow at what minimum rate of increase?

MODE: COMP FSE (for FIX) TAB 5

Display	**Key in**	
	INT TITLE COMP	
n = ?	5 COMP	
f = ?	Exp 6 COMP	
p = ?	Exp 5 COMP	
i = 0.58489		58.5% per year

How many years will it take to reach a goal of $100,000 in savings if the initial amount put aside is $20,000 at 11%?

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**
	INTPER TITLE COMP
f = ?	100000 COMP
p = ?	20000 COMP
i = ?	.11 COMP
n = 15.42 (years)	

Amortization

The monthly payment on a loan or mortgage is expressed as:

$$\text{Payment} = \text{PV} \div \left[\frac{1-(1+i)^{-n}}{i}\right]$$

where PV = present value (amount of the loan)
i = interest rate per period
n = number of payments

i = Interest Portion of Payment = Principal Remaining × I
v = Principal Portion of Payment = Payment − Interest Portion
r = Principal Remaining = Previous Principal Remaining − Principal Portion

(1) Programming 1

MODE: AER

Display	**Key in**
TITLE?	A M O R T ENT VAR p = VAR P ÷ ((1 − (1 + I)Y^x (−) N) ÷ I, ↳ X + 1 STO X, VAR i = VAR PI, VAR v = p − i, VAR P − VAR v VAR STO P, ↰ ENT

(2) Program execution 2

A company plans to borrow a million dollars for 10 months at 13%. Payment will be made in equal monthly installments. What is the monthly payment? And show the monthly breakdown.

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**
	Exp 6 STO P 10 STO N .13 ÷ 12 STO I 0 STO X AMORT TITLE COMP
p = 106054.62	COMP
	:

ANS 2, 6, 10, etc. (Payment #)	i	v	ANS 5, 9, 13, etc. (Principal Remaining)
1	10833.33	95221.28	904778.72
2	9801.77	96252.85	808525.87
.	.	.	.
.	.	.	.
.	.	.	.
9	2261.04	103793.57	104918.00
10	1136.61	104918.01	0.00

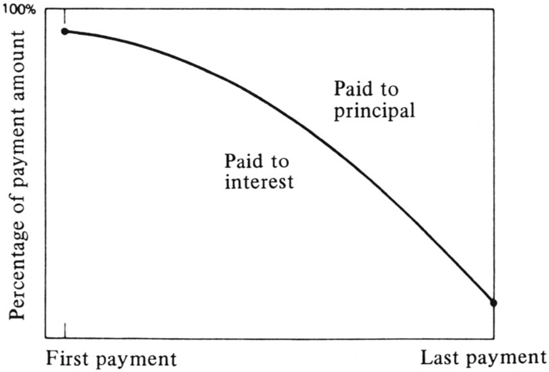


Figure 21

(3) Programming 2

MODE: AER

Display	**Key in**
TITLE?	C O N S T - P R I N ENT
M:	VAR v = VAR P ÷ N, ↳ X + 1 STO X VAR i = VAR PI, VAR p = v + i, VAR P VAR − v VAR STO P, ↰ ENT

(4) Program execution 2

Calculate for the same loan as the previous examples:

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**
	0 STO X Exp 6 STO P .13 ÷ 12 STO I 10 STO N TITLE COMP

Principal Amount = 100000.00

Payment #	i	Payment	Principal remaining
1	10833.33	110833.33	900000.00

2	9750.00	109750.00	800000.00
	.	.	.
	.	.	.
	.	.	.
9	2166.67	102166.67	100000.00
10	1083.33	101083.33	0.00

Cash Flow Analysis

Disconnected Cash Flow (DCF) provides the average rate of compound interest earned by a project on money invested over the life of the project. DCF discounts the annual cash flows to properly reflect the time value of money on a continuous compound interest basis. The rate of return and net present value of a DCF are based on the cash flow from earnings for each period. The cash flow is usually the sum of the net profit and depreciation. Any sales of land and equipment at the end of the project are included in the cash flow for the last period.

If the investor has a minimum return to achieve on an investment, then the Net Present Value (NPV) technique is used. If the NPV is positive, the project goal has been achieved. If negative, profit objectives have not been met. The NPV of future cash flows is represented by the series:

$$\mathrm{NPV} = -\mathrm{INV} + \frac{C^1}{(1+i)^1} + \frac{C^2}{(1+i)^2} + \ldots + \frac{Cn}{(1+i)^n}$$

where INV = initial investment
Cn = cash flow for a period
i = desired rate of return

The Internal Rate of Return (IRR) uses the same formulas as NPV with NPV equal to 0. The actual IRR is arrived at by iteration, taking successive guesses at the value of i until the NPV is near 0.

Program Notes:

With each cycle of the program, the cash flow for the period (C) is inserted. The initial investment is deducted from the total to get the Net Present Value. The future value of the invested capital is determined using the interest program.

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	C A S H ENT
M:	f()= C f()= X + 1 STO X, C ÷ (1 + I)Y^x X STO D + A STO A N > X −Y→[] ↰ −Y→[] −N→[] VAR npv = VAR A − B, ► −N →[] ENT

(2) Program execution

An investor wishes to make a five-year investment in a piece of property which can be used as a parking lot. The property will cost $200,000 and is expected to appreciate in value at the rate of 10% per year. The investor wants an annual rate of return of 20%. The net cash flow for the parking lot is:

Year	Amount
1	$30,000
2	45,000
3	24,000
4	52,000
5	40,000

Will the investor achieve a 20% rate of return and what is the actual IRR?

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**
	0 STO A 0 STO X 5 STO N .2 STO I 200000 STO B FUT TITLE (If the title FUTVAL does not appear, go to AER mode and key in this program from the "Interest Calculations" section.)
	COMP
p = ?	B COMP
i = ?	.1 COMP
n = ?	5 COMP
f = 322102.00	STO F
	CASH TITLE COMP
c = ?	30000 COMP
ANS 1 = 1.00	COMP
c = ?	45000 COMP
ANS 2 = 2.00	COMP
c = ?	24000 COMP
ANS 3 = 3.00	COMP
c = ?	52000 COMP
ANS 4 = 4.00	COMP
c = ?	40000 + F COMP
ANS 5 = 5.00	COMP
npv = 40736.72	

The positive NPV indicate that the investor will achieve a greater than 20% rate of return.

Determine the actual IRR:

Try 30%: Repeat the previous procedure with .3 STO I:
npv = −23640.63

The negative sign indicates IRR is less than 30%.
Try 25% with .25 STO I.
npv = 5040.78

Positive NPV shows return greater than 25%.
Try 26% with .26 STO I.
npv = −1197.76

The IRR is between 25% and 26%.

IRA Analysis

An Individual Retirement Account (IRA) is a trust created by the taxpayer to provide retirement income. The maximum amount that can be contributed by an individual is $2,000 each year. This contribution is free of federal income tax until it is actually used. The interest accumulations are treated in the same way.

If withdrawals are made prior to age 59 1/2, an excise tax of 10% is charged on the amount withdrawn.

The program for analyzing the IRA accumulation compares this amount to NON-IRA accumulation at a specified point in time. It is assumed that a contribution of $2,000 is made each year and steady interest is received at a rate of 10% under each plan.

For comparison purposes, the IRA is reduced by the tax rate used at the end of the period. The interest accumulated on the NON-IRA plan is also reduced by the same amount. If the percentage shown at the end of the program is less than 100%, it will not be advisable to establish an IRA account.

Program Notes: Use the formula for the value of regular payments made at the beginning of the period.

$$FV = PMT \times \frac{[(1+i)^n - 1]}{i}(1+i)$$

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	I R A ENT
M:	2ndF 1 VAR p VAR I×(1 − VAR t) VAR STO A, A − VAR p×n) VAR STO B×(1 − VAR t) VAR STO C + VAR p×n) VAR STO D, INT (A ÷ D×100 + 0.5) SUB
1:	(1 + VAR i) Y^x n − VAR 1) ÷ VAR i)×VAR (1 + VAR i) VAR STO I ENT

(2) Program execution

At a tax rate of 30% and for a period of 20 years, compare the two methods of accumulation.

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**	**Notes**
	I R A TITLE	
	COMP	
i = ?	.1 COMP	
n = ?	20 COMP	

p = ?	2000 COMP	
t = ?	.3 COMP	
ANS 1 = 88203.50	COMP	IRA Accumulation
ANS 2 = 73742.45	COMP	Non-IRA Accumulation
ANS 3 = 120.00		

IRA provides 19% greater amount at the end of the period.

Present Worth of a Bond

The present worth of a bond at issue is equal to the present worth of the coupon annuity plus the present worth of the maturity payment

$$PW = A\frac{[1-(1+r)^{-n}]}{[r]} + \frac{F}{(1+r)^{n}}$$

A good "buy" is a bond whose present worth is greater than its actual cost.

(1) Programming

MODE: AER

Display	**Key**
TITLE?	B O N D ENT
M:	VAR a×VAR((1 − (1 + VAR r)Y^x (−)n) ÷ r) + f ÷ VAR (1 + VAR r)Y^x n ENT

(2) Program execution

A $5,000 bond discounted 5% will pay $550 per year for 20 years. The payments, at 11%, are made annually. What is the bond's present worth?

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**
	BOND TITLE COMP
a = ?	550 COMP
r = ?	.11 COMP
n = ?	20 COMP
f = ?	4750 COMP

ANS 1 = 4968.99 (dollars)

Yield to Maturity

The true rate of interest of a bond is represented by a combination of this cost versus value at maturity and receipts from its coupons. The true rate is represented by r in the following equation:

$$Po = \Sigma \frac{I}{(1+r)^t} + \frac{M}{(1+r)^n}$$

where I = payment rate (coupon)
Po = Current price of the bond
M = Face value or value at maturity
n = number of years to maturity
t = takes the value of 1 to n

To determine the yield the value of r is estimated until the right side of the equation is equal to Po.

Program Notes:

A double loop is used. The first loop calculates the value of the series of interest payments. The second loop asks for a new rate if the previous rate did not result in a value (E) within 10 of the purchase price (P). ABS is used to eliminate negatives. A value like 10 is used because it would probably be impossible to reach a C which is exactly the same as P. For greater accuracy a value lower than 10 can be chosen. In the second loop the values of T and B are reset to 0 each time.

(1) Programming

MODE: AER

Display	**Key in**
TITLE?	Y I E L D ENT
M:	f()= R f()= 0 STO T 0 STO B ↳ T + 1 STO T N + 1 > T −Y→[] I ÷ (1 + R) Y^x T + B STO B, ↰ −Y→[] −N→[] B + M ÷ (1 + R) Y^x N STO C −N→[] ABS (C − P) > 10 −Y→[] ↰ −Y→ [] −N→[] R, ◣ −N→[] ENT

(2) Program execution

In 1985, a $1,000 bond maturing in 2005 sells for $1,080. The bond pays 12%, $120 annually. What is the yield of this bond?

MODE: COMP FSE (for FIX) TAB 2

Display	**Key in**
	1000 STO M 120 STO I 1080 STO P 20 STO N YIELD TITLE COMP
R = ?	

Try 12% : Key in .12 and press COMP 21 times.

If the displayed now shows R =, another rate must be tried.

Try 115%: Key in .115 and press COMP 21 times
Try 11%: Key in .11 and press COMP 21 times

Index

ABS, 97
Absolute Temperature, 58
AC Circuits, 53
Accelerated Depreciation, 81, 83
Accelerated Cost Recovery System, 81
Acceleration, 42
Amortization, 88
Angle, Phase, 51
Angle of Incidence, 61
Annuity, 96
Array, 16
Asset, 81
Astronomical Units, 42
Averages, Moving, 8

Balloon Payment, 87
Band Width, 56
Bandpass Filter, 55
Bank Material, 74
Beams, 64
Bending Stress, 64
Bonds, 96
Break-even, 77

Capacitance, Series, 49
Cash Flow, 91
Center of Gravity, 46
Centroid, 46
Chi-Square, 34
Comet, 42
Conditional, 1
Conduits, 63
Correlation, 22
Cosine, 13
Cosines, Law of, 4
Costs, 77
Counter, 35
Coupon, 97
Current Flow, 51
Curve Fitting, 29
Curves, Power, 27

Degrees of Freedom, 36
Definite Integral, 14
Deflection, 65
Demand, 77
Depreciation, 80
Determinate, 16
Digits, Internal, 14
Dimensions, 3
Disconnected Cash Flow, 91
Discriminant, 10
Double Loop, 97

Earthmoving, 74
Eccentricity, 39
Efficiency, Work, 73
Elasticity, 65
Ellipse, 39
Energy, Solar, 61
Excavator, 71
Exponential, 24

Feet, 3
Filter, 55
Fir, 66

Fittings, 63
Focus, 39
Frac, 3, 20
Frequency, 34
Fresnel, 61
Future Value of Money, 86

Gas, 58
Gravitation, 37, 42

Head, 63
Hemlock, 66

Ideal Gas, 58
Impedance, 50
Inch, 3
Inductors, 50
Installments, 89
INT, 3
Integral, 14
Internal Rate of Return, 91
Inertia, 45
Interest, 86
IRA, 94
Iteration, 91

Launch, 37
Law of Cosines, 4
Law of Sines, 4, 6
Linear Regression, 23
Load, 22
Loan, 88
Logarithmic Regression, 27
Loss, Pressure, 63

Mass, 38
Matrices, 16
Matrix, Inverse, 17
Maturity, Bond, 97
Mean Life, 33
Moment, 45
Mortgage, 88
Moving Average, 8
Multiple Feedback Filter, 55

Net Present Value, 91
Non-linear Regression, 24

Ohm's Law, 53
Op-amp, 55
Orbiting, 38

Parallel Reactance, 53
Parallel Resistance, 49
Parentheses, 1
Payment, 88
Phase Angle, 52
Pipe Laying, 72
Planet, 38
Polar Angle, 39
Polynomial, 11
Power Curves, 27
Present Value, 86
Present Worth, 96
Pressure, 63
Pressure Loss, 63
Price, 77
Principal, 88
Projectile, 37

Quadratic, 9

Radians, 40
Radiation, 61
Radius of Gyration, 45
Random Numbers, 20
Reactance, parallel, 53
Reactance, series, 50
Reflectance, 61
Refractive Index, 61
Regression, 23
Replacement Costs, 81
Resistance, parallel, 49
Roots, 9

Salvage Value, 81
Savings, 88
Search, 1
Series, 13
Series Capacitance, 49
Series Reactance, 50
Sener Construction, 72
Shearing, 65
Sines, Law of, 4, 6
Small Samples, 32
Soil Swell Factor, 72
Solar Energy, 61
Statistics, 22
Storage, 2
Store Memory, 22
Straight-line Depreciation, 81
Stress, 64
Subroutine, 1, 3, 17
Sum-of-the-Years'
  Digits Depreciation, 84
Supply, 77

"t" test, 32
Temperature, 58
Three-variable Linear
  Equations, 19
Time, 74
Time Value of Money, 91
Title, 1
Trenching, 71
Triangles, 4

Uniform Load, 64

VAR, 4
Variables, 3
Variance, 34
Velocity, 43

Wood Beams, 64

Yield, 97

SERVICE CENTER ADDRESS

SHARP ELECTRONICS CORPORATION
SHARP SERVICE CENTER
430 East Plainfield Road
Countryside, Ill. 60525
(312) 482-9292

SHARP

SHARP ELECTRONICS CORPORATION

CORPORATE HEADQUARTERS AND EXECUTIVE OFFICES:
Sharp Plaza, Mahwah, New Jersey 07430, Phone: (201)529-8200
REGIONAL SALES OFFICES AND DISTRIBUTION CENTERS:
Eastern: Sharp Plaza, Mahwah, New Jersey 07430, Phone: (201)529-8200
Midwest: 430 East Plainfield Road, Countryside, Illinois 60525, Phone: (312)482-9292
Western: Sharp Plaza 20600 South Alameda Street, Carson, California 90810, Phone: (213)637-9488

SHARP CORPORATION
OSAKA, JAPAN

SHARP

EXPLORING THE SCIENCES II

Applications for the SHARP EL-5150 Scientific Calculator

With the EL-5150, SHARP takes the uncertainty out of scientific calculating. Its unique alphanumeric display lets the user view the complete equation, including all functions and variables, before computing. It can also play back after computing, for double-checking and editing. The machine's functions include prompting the user to input selected variables, and then solving equations automatically. With its computing power and entry verification system, the EL-5150 provides the sure accuracy a serious user needs.

This text is intended to take the user beyond the instruction manual, to explore problems in :

- Algebra
- Geometry
- Trigonometry
- Matrices
- Decimal Conversion
- Statistics
- Regression
- Physics
- Electronics
- Mechanics
- Chemistry
- Business and Finance

The examples are designed to accent the machine's unique and convenient features. They are intended to provide a solid background, so that users can expand to projects beyond this text. The EL-5150 is ideal for professionals and advanced students in all fields that require double-checked accuracy.

Printed in Japan/Imprimé au Japon
6G3T(TINSE4631CCZZ)